HIRDLS

HIGH RESOLUTION DYNAMICS LIMB SOUNDER

Originators: John G. Whitney and Douglas M. Woodard Date: 2000-02-02

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Oxford University
Department of Atmospheric, Oceanic, and Planetary Physics
Parks Road
Oxford OX1 3PU, United Kingdom

University of Colorado at Boulder
Center for Lower Atmospheric Studies
3300 Mitchell Lane, Suite 250
Boulder, Colorado 80301-6303
United States of America

EOS

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HIRDLS Instrument Technical Specification
SP-HIR-013U

Prepared by: Douglas M. Woodard

Approved by:

John J. Barnett, UK Principal Investigator — Date

John C. Gille, US Principal Investigator — Date

John G. Whitney, Program System Engineer — Date

Raymond L. von Savoye, Instrument System Engineer, LMMS — Date

Steve Richard, Instrument Program Manager, LMMS — Date

Nigel Morris, UK Program Manager — Date

Neil F. Martin, HIRDLS Instrument Manager, GSFC — Date

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Change Log

Rev. U Changes from Rev. T

NOTE: To keep this list to a reasonable length, corrections of obvious typographical errors and minor formatting changes have been omitted from the Change History.

Incorporated Approved ATCs

None.

Non-ATC Changes by Section Number

Signature Page
Deleted: Dials, Loh, Howard
Added: Richard, von Savoye, Martin

1.1 HIRDLS Background Information
Updated text to reflect transfer of Instrument contract to GSFC.

2.1 Government and EOS Project Documents
Explicit revisions added for GIRD and MAR.

2.3 HIRDLS Program Documents
Added: SP-HIR-111, Thermal Interface Requirements Document
SW-HIR-147B, SAIL Requirements Document
SP-HIR-169, HIRDLS Power Distribution, Switching & Grounding
SP-HIR-212 through SP-HIR-289, Interface Control Documents

Deleted: TP-HIR-007, Pre-Launch Calibration Plan [not referenced in the ITS]
SP-HIR-014, External Interface Description [not referenced in the ITS]
TC-HIR-057, SPRAT [not referenced in the ITS]
SP-HIR-2XX, Internal Interface Control Documents (IICDs)

2.4 Information Documents
New section.
Added: TC-HIR-057, SPRAT [moved from Section 2.3]
SP-HIR-200, Internal Interface Control Document (System Section)

3.3.3.1 Within a Single Channel
Changed from a requirement to a guideline.

3.3.3.2 Between Channels
Changed from a requirement to a guideline.

3.4.9 In-Flight Radiometric Calibration
Deleted "at most".

3.4.9.1 In-Flight Calibration Mirror
New section containing IFC Paraboloid Mirror requirements previously in Section 4.6. These requirements have been updated per JGW, WPR and RWL input.

3.5.1.4 Fixed Angle Mode
Paragraph a: deleted "over the lifetime of the instrument,".

3.5.3.3.3 Optical Cube Documentation
Deleted first sentence; now applies only to the IAC.

3.6.2.2 Center of Mass Measurement
"Instrument origin as defined in the IICD" replaced with "IRCF".

3.6.3.3.1 Sunshield Door Disturbance
New section incorporating the previous first paragraph of Section 4.2.4.3.2, since this is an instrument-level requirement.

3.6.6.3 Drive Mechanism Torque Margin
Wording revised to reference Section 3.4.5.3 of the MAR.

3.7.7 Temperature Sensors
Table 3.7.7-1: Group 1 Accuracy limits relaxed from ±0.40; ±0.25;±0.40 to ±0.75; ±0.5;±0.75.

3.12 Contamination Control Requirements
First paragraph: replaced reference to HISCD with reference to PA-HIR-006.

3.13.2 Operational Life
Operational ife requirement changed from 7 to 8 years to be consistent with integration/test/calibration schedule.

3.13.4 Data Reliability
First paragraph added to clarify that this is a design requirement that is not to be verified by test or analysis.

4.1.3.5 Access
"IICD" replaced with "HSICD".

4.1.5.4 Thermal Interfaces
Requirements reference changed from IICD to SP-HIR-111.

4.1.3.7 Mechanical Interfaces
Section rewritten; relevant mechanical ICD summary table added.

4.1.4.3 Electrical Interfaces
IICD reference replaced with reference to Table 4.1.3.7-1.

4.1.5.2 Thermal Blankets
Requirements reference changed from IICD to SP-HIR-111.

4.1.5.3.2 [Deleted]
Was "Accommodation for Laboratory Cooling".

4.2.3.1 Closure and Shielding
Beam clearance requirement replaced with reference to SP-HIR-224.
Door opening range deleted (now defined in SP-HIR-050, SSH SSD).

4.2.4.1 Envelope
Added reference to SP-HIR-212.

4.2.4.2 Mass
Section renamed –was "Mass Properties". Deleted documentation requirements for C of M and moments of inertia.

4.2.4.3.2 Door Motion Disturbances
First paragraph moved to new Section 3.6.3.3.1; second paragraph revised with IICD reference removed.

4.2.4.4 Mechanical Interfaces
Contents of this section replaced with reference to SP-HIR-212.

4.2.5 Electrical Requirements
Changed generic IICD reference to SP-HIR-227.

4.2.5.1.2 Secondary Power
Changed generic IICD reference to SP-HIR-227.

4.2.5.3 Electrical Interfaces
Changed generic IICD reference to SP-HIR-227.

4.2.6 Thermal Interfaces
Requirements reference changed from IICD to SP-HIR-111.

4.3.3.1 Digital Rate Output
First paragraph: TBD resolved to 20 µs after trailing edge of GSS Synch; TBV removed.
“Gyro Data Strobe” changed to “GSS Synch” to match terminology in SP-HIR-237.

4.3.3.2 Angular Measurement Requirements
First paragraph: TBVs removed; rate input requirements changed to be with respect to the TRCF principal axes. Last sentence: deleted " for periods of up to (TBD) s".
Second paragraph: Restructured as a note; deleted " data for periods..." to end of paragraph.

4.3.3.2.1 Elevation Requirements
Second paragraph: removed TBV.
Third paragraph: "(TBD) arcsec" changed to "2.0 arcsec" in two places.

4.3.3.3 Survival Rates
TBD survival rate resolved to 360 °/s about any axis. Duration requirement deleted. Recovery time requirement deleted.

4.3.3.4 Warm-up Time
TBDs resolved to 4 hr and 8 hr for operation in air and vacuum, respectively.

4.3.4.1 Gyro Subsystem Envelope
Changed generic IICD reference to SP-HIR-213 and SP-HIR-234.

4.3.4.3 GMU-GEU Interconnection
Cable length changed from 1 m to 2 m; TBV removed.

4.3.4.5 Mechanical Interfaces
Entire paragraph replaced by references to SP-HIR-213 and SP-HIR-234.

4.3.5.3 EMI/EMC Requirements
Second paragraph: "static" deleted; TBD resolved to 500 µT.

4.3.5.4 Electrical Interfaces
Second paragraph reworded to require only that the subsystem withstand shorts from any test point to the shell or to any other test point; TBD removed.

4.3.5.4 Electrical Interfaces
Changed generic IICD reference to SP-HIR-237 and SP-HIR-239.

4.3.6.2.1 GMU Thermal Interface
Changed thermal interface reference from IICD to SP-HIR-111.

4.3.6.2.2 GEU Thermal Interface
Changed thermal interface reference from SP-HIR-213 to SP-HIR-111.

4.3.7 Control and Data Requirements
Changed requirements reference to C&TH and SP-HIR-237.

4.4.3.5 Spectral Performance
Section renamed - was “Spectral Bands”. Text revised to require support the instrument-level spectral requirements.

4.4.3.9 [Deleted]
Was “Optical Interfaces”.

4.4.3.9.1 [Deleted]
Was “TSS to DSS Optical Interface”.

4.4.3.9.2 [Deleted]
Was “TSS to IFC Optical Interface”.

4.4.5.1.2 Elevation Axis
Paragraph a: axis orthogonality requirement relaxed from 0.05° to ±0.07°; added requirement that this apply over the elevation axis motion range specified in Section 4.4.10.1.
Paragraph b: parallelism of elevation axis to mirror surface relaxed from 0.025° to ±0.05°

4.4.5.2.1 TSS Stiffness
Removed TBV.

4.4.5.6 TSS Mechanical Interfaces
Added subsections 4.4.5.6.1-4.4.5.6.4 with explicit ICD callouts.

4.4.6.2 TSS Electrical Interfaces
Replaced generic IICD reference with specific references to SP-HIR-247 and SP-HIR-249.

4.4.7.1 Thermal Interfaces
Changed IICD reference to SP-HIR-111.

4.4.7.2 [Deleted]
Was “Operational Heaters”; requirement was TBD.

4.4.10.4 Calibration Aids
Flatness requirement relaxed from $\lambda/10$ at 546 nm to $\lambda/2$ at 633 nm.

4.5.4.2.1 Responsivity Uniformity
Changed from a requirement to a design goal.

4.5.5.1 Envelope
Replaced generic IICD reference with reference to SP-HIR-245.

4.5.5.3 Mechanical Interface
Replaced generic IICD reference with reference to SP-HIR-245.

4.5.6.4 Electrical Interface
References to Section 4.7 and to the IICD replaced with a reference to SP-HIR-257.

4.5.7.1 Thermal Interface
IICD reference changed to SP-HIR-111 reference.

4.6.1 Subsystem Description
Section rewritten to be consistent with the IFC paraboloid mirror having been relocated from the IFC (Subsystem) to the TSS.

4.6.5.1 Envelope
Envelope requirements reference changed from IICD to SP-HIR-216 and SP-HIR-246.

4.6.5.3 Mechanical Interface
Reference changed from IICD to SP-HIR-246.

4.6.5.4 [Deleted]
Was “Stability Requirements”; requirements were TBD.

4.6.6.1 IFC Subsystem Secondary Power Requirements
Deleted "the IFC controller electronics located in"; changed interface reference from Section 4.7 to SP-HIR-267.

4.6.7.1 Temperature Range
Deleted requirements related to the IFC paraboloid mirror (see new Section 3.4.9.1).

4.6.7.2 Temperature Sensing
Deleted requirements related to the IFC paraboloid mirror, including requirement “c” in its entirety (see new Section 3.4.9.1).

4.6.7.4 Thermal Interfaces
TBD resloved with reference to SP-HIR-111.

4.7.1 Subsystem Description
Contents of previous Section 4.7.1.2 added to text of this section; Figure 4.7.1.2-1 renumbered to Figure 4.7.1-1.

4.7.1.1 Architectural Philosophy
Changed “shall” to “will” or “should”, as appropriate, in 4 places.

4.7.1.2 Subsystem Interfaces
Section heading was “Functional Interfaces Description”; text moved to Section 4.7.1.

4.7.1.2.1 [Deleted]
Was “User Interface”.

4.7.2 Modes of Operation
Second paragraph moved to Section 4.7.4.

4.7.3.1 Spacecraft and Subsystem Interfaces
Section renamed, was “Logical Interfaces”. Text deleted.

4.7.3.1.1 Spacecraft Command and Telemetry (C&T) Interface
References updated to include C&TH and HSICD.

4.7.3.1.2 Gyro Subsystem Interface
Requirements referenced updated to include SP-HIR-237 and C&TH.

4.7.3.1.3 Telescope Subsystem Interface
Revised to reference SP-HIR-247 and the C&TH.

4.7.3.1.4 Detector Subsystem Interface
Revised to reference SP-HIR-257.

4.7.3.1.5 IFC Subsystem Interface
TBD resolved; now references SP-HIR-267 and the C&TH.

4.7.3.1.6 Sunshield Subsystem Interface
Revised to reference SP-HIR-227 and the C&TH.

4.7.3.1.7 Cooler Subsystem Interface
Revised to reference SP-HIR-278 and the C&TH.

4.7.3.1.8 Operational Heaters Interface
Reworded to refer to operational heater interface defined in SP-HIR-247.

4.7.3.2.1.3.2 Memory Dump and Diagnostic Data
First sentence of second paragraph, including a TBD, replaced by a new last sentence of this paragraph requiring that diagnostic data in the Science data stream comply with GIRD 6.5.10.

4.7.3.2.2.1 Functional Description
Last paragraph: deleted requirement for optional operation from an externally supplied master clock; substituted requirement for optional operation from an externally supplied synchronization signal in lieu of the Chopper Reference Signal.

4.7.3.2.2.2.1 Output Frequencies , Waveforms and Timing
Deleted first paragraph, including a TBD.

4.7.3.2.4.2.5 TSS Performance Data
Deleted second sentence, including TBD.

4.7.3.2.6.6 [Deleted]
Was “Scanner Code and Parameter Load Commands”; requirement was TBD.

4.7.3.2.7 IFC Temperature Control
Functional interface reference changed from the IFC-IPS ICD to the C&TH.

4.7.3.2.8.1 Sunshield Drive Mechanism Control
Interface requirements reference changed from IICD to SP-HIR-227.

4.7.3.2.8.2 Sunshield Hold-down and Release Mechanism Control
Interface requirements reference changed from IICD to SP-HIR-227.

4.7.3.2.10 Operational Heater Control
Deleted last paragraph and table containing only TBDs.

4.7.3.2.12.3 User Processes
Entire text replaced with a reference to SW-HIR-147B.

4.7.3.2.12.4 Real-Time Executive Functions
Deleted third paragraph, including TBD.

4.7.3.2.14 [Deleted]
Was “Memory Management”; requirement was TBD.

4.7.3.2.15 [Deleted]
Was “Background Testing”; requirement was TBD.

4.7.4 IPS Software Requirements
New first paragraph is the previous second paragraph of Section 4.7.2.

4.7.5.1.1.1 [Deleted]
Was “Data Types Supported”; requirement was TBD.

4.7.5.1.1.2 [Deleted]
Was “Operations Supported”; requirement was TBD.

4.7.5.1.2.1.2 Reprogrammable Memory
Paragraph a: deleted all text, including TBD, after “...electrically modifiable”.

4.7.5.2.2 Envelope
Requirements reference changed from IICD to SP-HIR-217.

4.7.5.3.3 Signal Electrical Interfaces
Text revised to point to Section 4.7.3.1; subsections deleted.

4.7.7.2 Thermal Interfaces
Changed thermal requirements reference from SP-HIR-217 to SP-HIR-111.

4.7.8 Reliability Requirements
Second paragraph added to clarify that the control/data reliability requirements in Subsections 4.7.8.1-4.7.8.5 are design guidelines for which formal verification is not required.

4.8 Cooler Subsystem
Entire section updated (Reviewers: Please check entire section.). Additional 4.8.X changes made during the review period are listed below.

4.8.4.1.3 Secondary Power
Deleted all but the first sentence.

4.8.4.2.1 Primary Power Grounding
Isolation requirements for primary to chassis and primary to secondary relaxed from 10 MΩ to 2 MΩ reflecting the fact that only the CSS and PSS connect to the Noisy Bus.

4.8.4.2.2 Secondary Power Grounding
Replaced all text with a requirements reference to SP-HIR-169, Section 7.5.

4.9.4.4 Control and Data Requirements
Added requirements reference to the C&TH.

4.9.5.1 Thermal Interfaces
Requirements reference changed from SP-HIR-219 to SP-HIR-111.

5.1 Subsystem Allocations
Tables updated per Lanham input.

6.2 [Deleted]
Was “Packing, Shipping Containers”; requirement was TBD.

7.1 Acronym List

Added:

BEU	Blackbody Electronics Unit
CMA	Cooler Mechanical Assembly
ITGSE	Instrument Thermal Ground Support Equipment

Deleted:

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Contents

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1 SCOPE

1.1 HIRDLS Background Information

The High Resolution Dynamics Limb Sounder (HIRDLS) Instrument Program is an international joint development project between the US and the UK. The US team consists of the University of Colorado at Boulder, Lockheed Martin Missiles and Space (LMMS), and their subcontractors. The UK team consists of Oxford University, Rutherford Appleton Laboratory (RAL), and their subcontractors. There are joint principal investigators for this project: Dr. John C. Gille of CLAS and Dr. John J. Barnett of Oxford University. The lead system engineer is from the UK team at Oxford University. Each country is providing the resources necessary to perform the tasks it has agreed to in Work Share Agreement (WSA - between RAL and NASA Goddard Space Flight Center) for designing, fabricating, testing, and calibrating the Instrument.

The HIRDLS Instrument will be a multi-channel limb-viewing infrared (IR) radiometer for high resolution monitoring of upper tropospheric, stratospheric, and mesospheric temperature, trace chemicals, and geopotential height gradients. These are the key elements that are needed to understand the chemistry and dynamics of those regions, including the roles of planetary and gravity waves in transporting and mixing radiatively and chemically active species that are important to climate change. The Instrument will have a better vertical resolution than previous limb sounders, because of its smaller field of view (FOV) and other technical factors; and the horizontal spacing between the profiles will be much closer, since the instrument will be able to scan azimuthally. A gyroscope package will measure the motion of the optical bench along three axes. This will allow pressure level determinations at different locations to be related to one another, and it will make the deduction of the gradients of geopotential surfaces possible. The Instrument will have flexible on-board computational capabilities, and its actions will be controllable and programmable from the ground. Filters will be used to select radiation from narrow wavelength regions, chosen to optimize chemical identification and to facilitate the determination of, and the correction for, aerosol emission. Consequently, the measurements will be valid down to lower levels (viz., 8 km or less) than with previous limb sounders.

The principal novel characteristics of the Instrument are:

- Improved horizontal resolution
- Improved vertical resolution
- Improved ability to sound the tropopause region
- Ability to sound a large number of trace species with a range of chemical lifetimes

HIRDLS is planned for flight on the Earth Observing System (EOS) Chemistry Mission (CHEM) Platform, currently scheduled to be launched in 2002. The science requirements and objectives for the project are discussed in the Science Requirements Document (SRD), SC-HIR-12. The science-derived instrument requirements are provided in the Instrument Requirements Document (IRD), SC-HIR-18.

1.2 Scope of this Document

This document is the technical specification for the design and performance of the HIRDLS Instrument and its major subsystems.

Beginning with ITS Revision P, the requirements contained herein apply to the HIRDLS Instrument before radiometric calibration in the UK.

For reference:

- The post-calibration, pre-launch knowledge and performance requirements are contained in document SP-HIR-164, Pre-Launch Calibration Requirements.
- The requirements relating to the post-launch data processing required to achieve the mission-level performance specified in SC-HIR-18, Instrument Requirements Document, will be addressed in the Algorithm Theoretical Basis Document for Level 1 HIRDLS Data.

2 APPLICABLE DOCUMENTS

Referenced documents form part of this specification to the extent specified herein. Unless a specific issue or revision is listed, each referenced document shall be of the most recent revision. In the event of a conflict between the ITS and any referenced document, the ITS shall take precedence.

2.1 Government and EOS Project Documents

FED-STD 209	Clean Room and Work Station Requirements, Controlled Environment
MIL-STD-462	Electromagnetic Interference Characteristics, Measurement of
MIL-STD-889	Dissimilar Metals
MIL-STD-1246B	Product Cleanliness Levels and Contamination Control Program
MIL-STD-1553B	Digital Time Division Command/Response Multiplex Data Bus
MIL-F-48616	Filters (Coatings), Infrared Interference: General Specification for
MIL-B-5087	Bonding, Electrical and Lightning Protection for Aerospace Systems
GSFC 311-INST-001	Instructions for EEE Parts Selection, Screening, and Qualification
GSFC 422-11-12-01, Rev. A, Change 3	General Interface Requirements Document (GIRD) for EOS Common Spacecraft/Instruments
GSFC 424-11-13-01, Rev. [none], Change 2	Mission Assurance Requirements (MAR) for the High Resolution Dynamics Limb Sounder - EOS Chemistry Mission
GSFC 424-28-21-06	Unique Instrument Interface Document (UIID) for the High Resolution Dynamics Limb Sounder (HIRDLS)
MSFC-HDBK 527	Material Selection List for Space Hardware Systems
NASA RP 1124	Outgassing Data for Selecting Spacecraft Materials
TRW-D26477	Interface Control Document for the High Resolution Dynamics Limb Sounder, EOS Common Spacecraft Project (HSICD)

2.2 Non-government Documents

ASTM-E-595	Total Mass Loss (TML) and Collected Volatile Condensable Materials (CVCM) from Outgassing in a Vacuum Environment
ANSI/ASQC Q9001-1994	Quality systems - Model for Quality Assurance in Design, Development, Production, Installation and Servicing
ANSI STD X3.159-1989	C Programming Language Standard, 1989
IEEE 1003.1-1988	Portable Operating System Interface for Computer Environments (POSIX) Standard for System Interface
ISO 1000	SI Units and Recommendations for the Use of Their Multiples and of Certain Other Units
ANSI/EIA/TIA-422-B-1994	Electrical Characteristics of Balanced Voltage Digital Interface Circuits

2.3 HIRDLS Program Documents

PA-HIR-003	Performance Assurance Implementation Plan (PAIP)
PM-HIR-004	Configuration Management Plan
PA-HIR-006	Contamination Control Plan
TP-HIR-008	Performance Verification Plan
SC-HIR-012	Science Requirements Document (SRD)
SC-HIR-018	Instrument Requirements Document (IRD)
SP-HIR-090	Fiducial Atmospheric Radiance Profiles
SW-HIR-096	Flight Software Management Plan for HIRDLS
SP-HIR-103	Command & Telemetry Handbook (C&TH)
SP-HIR-111	Thermal Interface Requirements Document
SW-HIR-147B	SAIL Requirement Document
SP-HIR-169	HIRDLS Power Distribution, Switching & Grounding
SP-HIR-198	Baseline Scan Patterns for HIRDLS Design & Test
SP-HIR-212	STH to SSH Interface Control Document
SP-HIR-213	STH to GSS Interface Control Document
SP-HIR-214	STH to TSS Interface Control Document
SP-HIR-216	STH to IFC Interface Control Document
SP-HIR-217	STH to IPS Interface Control Document
SP-HIR-218	STH to CSS Interface Control Document
SP-HIR-219	STH to PSS Interface Control Document
SP-HIR-224	SSH to TSS Interface Control Document

SP-HIR-227	SSH to IPS Interface Control Document
SP-HIR-233	GEU to GMU Interface Control Document
SP-HIR-234	GSS to TSS Interface Control Document
SP-HIR-237	GSS to IPS Interface Control Document
SP-HIR-245	TSS to DSS Interface Control Document
SP-HIR-246	TSS to IFC Interface Control Document
SP-HIR-247	TSS to IPS Interface Control Document
SP-HIR-249	TSS to PSS Interface Control Document
SP-HIR-257	DSS to IPS Interface Control Document
SP-HIR-258	DSS to CSS Interface Control Document
SP-HIR-266	BEU to BB Interface Control Document
SP-HIR-267	IFC to IPS Interface Control Document
SP-HIR-278	IPS to CSS Interface Control Document
SP-HIR-279	IPS to PSS Interface Control Document
SP-HIR-289	CSS to PSS Interface Control Document

2.4 Information Documents

Documents listed in this section are for information only and may not be used as sources-by-reference for requirements.

TC-HIR-057	System Performance Requirements & Allocation Tables (SPRAT)
SP-HIR-200	Internal Interface Control Document (System Section)

3 INSTRUMENT SPECIFICATIONS

Unless otherwise stated, the performance specifications contained herein shall be taken to apply to the flight instrument immediately prior to pre-launch calibration.

3.1 Instrument Description and Definitions

HIRDLS is an IR radiometer designed to view the atmosphere of the earth at the limb from a 705 km sun-synchronous polar orbit. The optical line-of-sight (LOS) of the Instrument is directed at the limb, in the anti-velocity (backward) direction as the spacecraft orbits the earth. The Instrument measures atmospheric IR emissions in 21 spectral channels simultaneously, while scanning the limb vertically at different azimuth angles. The nominal mission duration in orbit is 5 years. These basic considerations have dictated the general features of the Instrument as shown in Figure 3.1-1.

All linear dimensions in object space given herein assume an object distance of 3000 km except as otherwise noted.

3.1.1 [Deleted]

3.1.2 [Deleted]

3.1.3 Coordinate Frames

Where a coordinate frame is required to describe a feature or a requirement of the Instrument, one of the following reference coordinate frames, as appropriate, is used:

3.1.3.1 Spacecraft Reference Coordinate Frame (SRCF)

The Spacecraft Reference Coordinate Frame is defined, in accordance with GIRD Section 9, as a right-handed rectangular coordinate system with the following axis definitions: +Z is toward the earth, along a line connecting the S/C center of mass to the earth center of mass; the Y-axis is normal to the instantaneous plane of the orbit with +Y on the anti-sun side; the X-axis completes the coordinate system, with +X in the general direction of the spacecraft velocity vector. The X, Y, Z axes correspond approximately to the Roll, Pitch, and Yaw axes, respectively, of the S/C.

3.1.3.2 Instrument Reference Coordinate Frame (IRCF)

The IRCF is a right-handed rectangular coordinate system having axes, when the Instrument is in orbit, nominally parallel to, and in the same directions as, those of the SRCF (defined in Section 3.1.3.1), but fixed with respect to the Instrument Baseplate.

The exact directions of the IRCF axes shall be determined by physical features of the baseplate assembly.

The origin of the IRCF is such that the IRCF coordinates of the Scan Mirror Datum Point (see definition “e” in Section 3.3), in the absence of alignment, positioning, and distortion errors, would be:

$$
\begin{aligned}
X &= +1500.00 \text{ mm} \\
Y &= +700.00 \text{ mm} \\
Z &= +800.00 \text{ mm}
\end{aligned}
$$

3.1.3.3 Telescope Reference Coordinate Frame (TRCF)

The TRCF is a right-handed rectangular coordinate system having axes nominally parallel to, and in the same directions as, those of the IRCF (defined in Section 3.1.3.2), but fixed with respect to physical features of the optical bench. These physical features shall be selected, to the extent practicable, for maximum dimensional stability with respect to the GMU and SMA mounting pads.

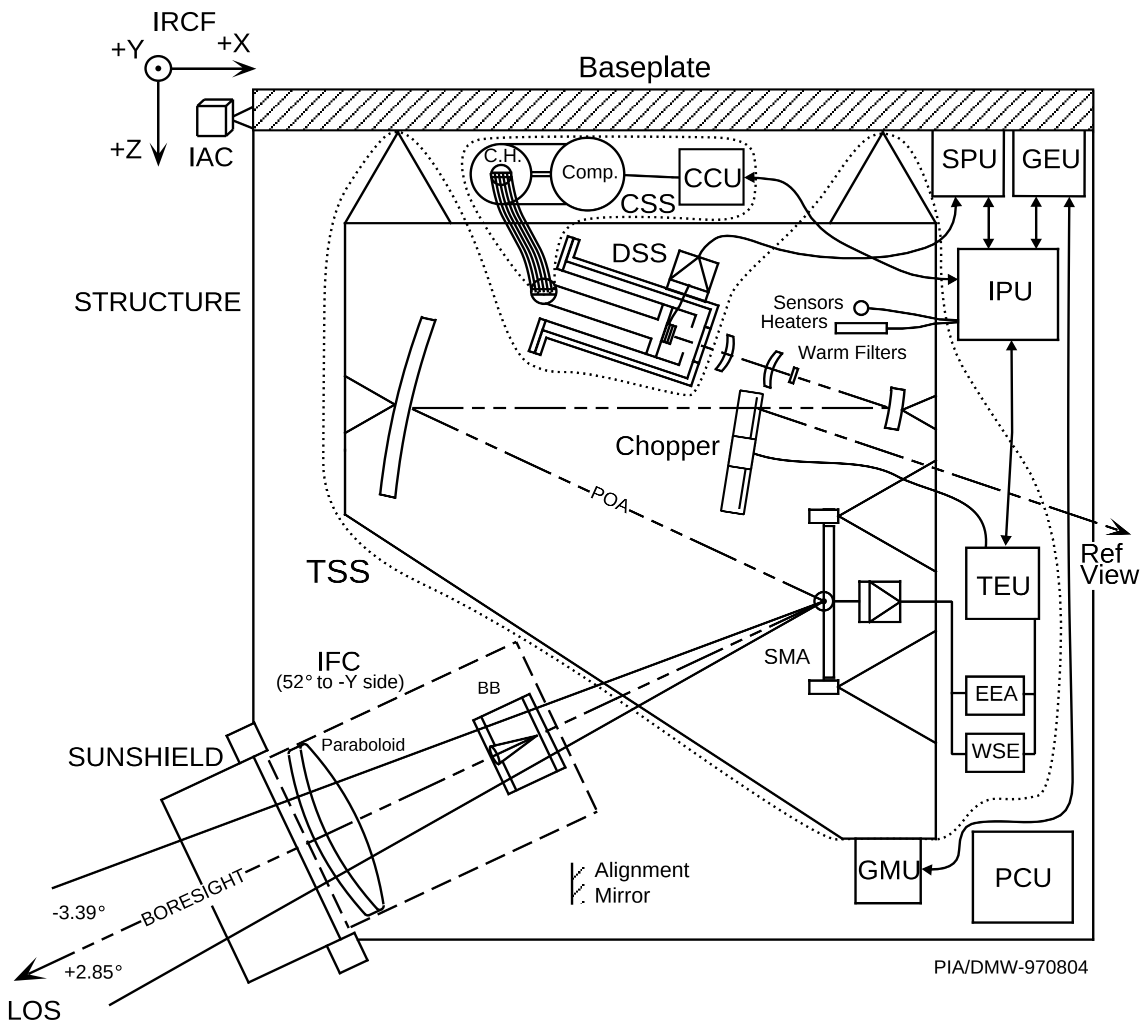


Figure 3.1-1 HIRDLS Instrument Layout

3.2 Modes of Operation

The Instrument shall be designed to support, as a minimum, the modes of operation defined in the following paragraphs. A summary of the functional states for all defined combinations of Instrument Modes and Submodes is given in Table 3.2-1.

3.2.1 Off Mode

In the Off Mode and related Submodes, the functional states of the Instrument shall conform to the state definitions given in the OFF column of Table 3.2-1.

3.2.2 Survival Mode

In the Survival Mode and related Submodes, the functional states of the Instrument shall conform to the state definitions given in the SURVIVAL column of Table 3.2-1.

3.2.3 Idle Mode

In the Idle Mode and related Submodes, the functional states of the Instrument shall conform to the state definitions given in the IDLE column of Table 3.2-1.

3.2.4 Low Power Mode

In the Low Power Mode and related Submodes, the functional states of the Instrument shall conform to the state definitions given in the LOW POWER column of Table 3.2-1.

3.2.5 Standby 1 Mode

In the Standby 1 Mode and related Submodes, the functional states of the Instrument shall conform to the state definitions given in the STANDBY 1 column of Table 3.2-1.

3.2.6 Standby 2 Mode

In the Standby 2 Mode and related Submodes, the functional states of the Instrument shall conform to the state definitions given in the STANDBY 2 column of Table 3.2-1.

3.2.7 Mission Mode

In the Mission Mode and related Submodes, the functional states of the Instrument shall conform to the state definitions given in the MISSION column of Table 3.2-1.

Scanning sequences for atmospheric data acquisition and in-flight calibration shall be controlled by user-defined routines resident in, or uplinked to, the IPS.

In the Default Mission Submode (Global Mode), acquisition of radiometric and pointing data shall occur at a fixed, uninterrupted rate.

The Special Mission Submode is intended to accommodate special tests, pitch-up calibrations, etc. that require science data acquisition, but do not fall within the scope of continuous data acquisition as in the Default Mission Submode. All instrument functions and facilities provided for the Global Mode shall be available during Special Mission Submode operation, but no specific performance requirements apply to this submode.

3.2.7.1-3.2.7.6 [Deleted]

3.2.8 [Deleted]

Instrument MODE ==>	OFF				SURVIVAL				IDLE				LOW POWER				STANDBY 1				STANDBY 2				MISSION	
MODE Number ==>	1				2				3				4				5				6				7	
Instrument SUB-MODE ==>	Default	Caged	Safe	Safe + Caged	Default	Caged	Safe	Safe + Caged	Default	Caged	Safe	Safe + Caged	Default	Caged	Safe	Safe + Caged	Default	Safe	Decontam	Safe + Decontam	Default	Safe	Decontam	Safe + Decontam	Default	Special
Quiet Bus (A or B)	off	off	off	off	off	off	off	off	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Noisy Bus (A or B)	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Survival Htr Bus (A and/or B)	off	off	off	off	ON	ON	ON	ON	undef [4]	undef [4]	undef [4]	undef [4]	undef	undef	undef	undef	undef	undef	undef	undef	undef	undef	undef	undef	undef	undef
IPU power	off	off	off	off	off	off	off	off	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
SPU power	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Instrument Processor running	no	no	no	no	no	no	no	no	YES [1]	YES [1]	YES [1]	YES [1]	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
TEU Scan Processor running	no	no	no	no	no	no	no	no	YES [1]	YES [1]	YES [1]	YES [1]	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
1553 bus functional	no	no	no	no	no	no	no	no	YES [1]	YES [1]	YES [1]	YES [1]	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Telemetry channels functional	no	no	no	no	no	no	no	no	some [1]	some [1]	some [1]	some [1]	some	some	some	some	YES [3]	YES [3]	YES [3]	YES [3]	YES	YES	YES	YES	YES	YES
Sunshield Door drive power	off	off	off	off	off	off	off	off	off	off	off	off	off [2]	off [2]	off [2]	off [2]	safe	safe	safe	safe	ON	ON	ON	ON	ON	ON
Sunshield Door cage status	un-latched	latched	un-latched	latched	un-latched	latched	un-latched	latched	un-latched	latched	un-latched	latched	un-latched	latched	un-latched	latched	un-latched	un-latched	un-latched	un-latched	un-latched	un-latched	un-latched	un-latched	un-latched	un-latched
Sunshield Door position [5]	undef	closed	safe	closed	undef	closed	safe	closed	undef	closed	safe	closed	undef	closed	safe	closed	undef	safe	undef	safe	undef	safe	undef	safe	undef	undef
Scan drive power	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	ON	ON	ON	ON	ON	ON
Scanner cage status	un-caged	motors shorted	un-caged	motors shorted	un-caged	motors shorted	un-caged	motors shorted	un-caged	motors shorted	un-caged	motors shorted	un-caged	motors shorted	un-caged	motors shorted	un-caged	un-caged	un-caged	un-caged	un-caged	un-caged	un-caged	un-caged	un-caged	un-caged
Scanner position	undef	undef	safe	safe	undef	undef	safe	safe	undef	undef	safe	safe	undef	undef	safe	safe	undef	safe	undef	safe	undef	safe	undef	safe	scanning	undef
Space View Aperture door [6]	undef	closed	undef	closed	undef	closed	undef	closed	undef	closed	undef	closed	undef	closed	undef	closed	undef	undef	undef	undef	undef	undef	undef	undef	OPEN	OPEN
Gyroscope subsystem power	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Operational Heaters	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	undef	undef	undef	undef	ON	ON	ON	ON	YES	YES
Radiometric temperatures stable	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	undef	undef	undef	undef	YES	YES
Cooler compressor cage status	un-caged	motors shorted	un-caged	motors shorted	un-caged	motors shorted	un-caged	motors shorted	un-caged	motors shorted	un-caged	motors shorted	un-caged	motors shorted	un-caged	motors shorted	un-caged	un-caged	un-caged	un-caged	un-caged	un-caged	un-caged	un-caged	un-caged	un-caged
Cooler power	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	off	ON	ON	ON	ON	ON	ON
Compressors running	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	YES	YES	undef	undef	YES	YES
Displacer running	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	undef	undef	no	no	YES	YES
Detector temperature status	undef	undef	undef	undef	undef	undef	undef	undef	undef	undef	undef	undef	undef	undef	undef	undef	undef	undef	undef	undef	undef	undef	undef	undef	COLD	COLD

Notes

1 When processor booting (if applicable) has completed
2 Except when UNCAGE Procedure run
3 Except CSS telemetry
4 Formally undefined but normally ON
5 Safe means any position between closed and 60 degrees open
6 Once opened on orbit, SVA door would normally remain open

Table 3.2-1 Instrument Modes of Operation

[Intentionally Blank]

3.3 Optical Specifications

The following definitions apply to the optical specifications in this document:

a. Projected Optical Axis (POA) - the ray through the optical system that originates at the center of the detector array (point X in Figure 4.5.1-1) and passes through the center of the system aperture stop.

b. Instantaneous Line Of Sight (ILOS) - the direction of the POA (toward the atmosphere) after reflection at the Scan Mirror

c. Scan Datum Position - the position of the Scan Mirror at which the reflecting surface is parallel to the TRCF Y-Z plane.

d. Boresight - the direction of the ILOS when the Scan Mirror is in the Scan Datum position.

e. Scan Mirror Datum Point - the point of intersection of the POA and the Scan Mirror reflecting surface when the Scan Mirror is in the Scan Datum Position.

f. Elevation and Azimuth Shaft Angles - The scan mirror will be mounted in a two-axis gimbal. The gimbal inner axis will be referred to as the elevation axis, and rotations of the scan mirror about that axis will be measured in terms of elevation shaft angles. The gimbal outer axis will be referred to as the azimuth axis, and rotations of the inner gimbal assembly about that axis will be measured in terms of azimuth shaft angles. Throughout this document, it is assumed that the elevation shaft angle and the azimuth shaft angle each takes a zero value when the scan mirror is in the Scan Datum Position, and that the positive sense of shaft rotation for each axis corresponds to the respective positive LOS angle direction as defined in Figure 3.5-1.

3.3.1 Vertical Field of View

At a scanner azimuth shaft angle of zero, the vertical angular response at the entrance pupil of each spectral channel shall be a function with a full width at half maximum (FWHM) of 333 +17, –33 µrad. At other azimuth shaft angles the vertical response FWHM shall not increase by more than the amount attributable to the image rotation produced by the scan geometry.

3.3.2 Vertical Response

The end-to-end vertical response of each spectral channel is specified herein with respect to an ideal line source perpendicular to the ILOS, parallel to the IRCF X-Y plane, and moving parallel to the IRCF Z axis. Define the center of the vertical IFOV as the midpoint between the half-maximum relative response points and let Δz be the distance (at the limb) from this center. The following requirements shall then be met:

a. The integrated vertical response between the half-maximum points must be at least 80% of the total integrated response.

b. For $\Delta z = 0.75$ km, the integrated response over the spatial interval $-\Delta z$ to $+\Delta z$ must be at least $(100 - 0.4\lambda)$% of the total integrated response, where λ is the central wavelength (in µm) of the channel.

c. For 1.0 km $\leq \Delta z \leq$ 4.0 km, the integrated response over the spatial interval $-\Delta z$ to $+\Delta z$ must be at least $(100 - 0.25\lambda / \Delta z^{1.15})$% of the total integrated response.

d. For $\Delta z > 4.0$ km, the vertical response function shall be governed by the Out-of-Field Response requirement in Section 3.3.5.

The requirements of this section apply only for ILOS elevation directions falling within the atmospheric sounding ranges specified in Table 3.4.3-1 and at a scanner azimuth shaft angle of zero.

3.3.3 Vertical Response Stability

3.3.3.1 Within a Single Channel

It is a design guideline that the long-term stability of the vertical IFOV profile of each channel between the initially determined 0.2% relative response points shall be such that the relative response averaged over any interval equal to one tenth of the IFOV in the vertical spatial dimension shall not change by more than 0.5% of the maximum response, over the lifetime of the Instrument in orbit.

3.3.3.2 Between Channels

It is a design guideline that over the lifetime of the Instrument in orbit, the change in vertical registration of the centroid of the vertical response function of any channel with respect to the center of the field stop array, shall not exceed 4.8 μrad.

3.3.4 Horizontal Field of View

The horizontal angular response at the entrance pupil of each spectral channel shall be a function with a full width at half maximum (FWHM) of 3.33 ±0.33 mrad.

3.3.5 Out-of-Field Response

For each channel, while viewing either the atmosphere or the IFC blackbody, the integrated response (including optical crosstalk) that corresponds to scene radiance from points in the FOV with $\Delta z > 4$ km (see Section 3.3.2) must be less than the greater of: (1) 1.0% of the total integrated response or (2) 100% of the specified radiometric noise. The HIRDLS document SP-HIR-90A specifies the atmospheric scene radiances that must be used to demonstrate compliance with this requirement.

3.3.6 Focus

3.3.6.1 Object Distance

The Instrument optics shall be designed for a fixed focus at an object distance of 3,000 ±300 km.

3.3.6.2 Active Focusing

No active focusing mechanism shall be employed. This requirement shall not preclude the use of active thermal control of any part of the Instrument, including optical elements.

3.3.7 Obscurations

For the purposes of the requirements in this section, the term "optical beam" shall be defined:

a. for any location along the optical axis between the detector array and the primary diffraction baffle (PDB), as the envelope of all geometric rays defined by the field and aperture stops situated immediately on either side of that location;

b. for any location along the optical axis on the atmosphere side of the PDB, as the envelope of all geometric rays defined by the PDB and the primary field mask.

There shall be no vignetting of the optical beam by any surface not specifically intended to be in the optical path, for all positions of the scan mirror within the specified elevation and azimuth atmospheric and IFC view scan ranges. At every location along the beam there shall be a radial clearance equal to the lesser of 3 mm or 10% of the beam diameter at that location. This requirement shall apply in the presence of the worst-case misalignment of the optical beam relative to the surrounding structure.

The requirements of this section shall apply with the OBA in orbit, or in a 1 g field with the Instrument Z-axis oriented within 30° of vertical.

3.3.8 Optical Transmission

Optical transmission averaged over each channel's Field of View, and over each channel's spectral passband between the 50% relative response points shall be greater than or equal to the values listed in Table 3.3.8-1. This requirement applies to the optical train between the main instrument aperture and each detector element with the chopper in the fully open position.

Channel	Transmission
1	0.135
2	0.251
3	0.303
4	0.304
5	0.349
6	0.401
7	0.411
8	0.540
9	0.500
10	0.512
11	0.567
12	0.510
13	0.510
14	0.539
15	0.516
16	0.483
17	0.521
18	0.482
19	0.326
20	0.516
21	0.507

Table 3.3.8-1 Optical Transmission Requirements

3.4 Radiometric Specifications

Unless otherwise stated, the following requirements apply with the chopper operating and the chopper reference view at the temperature expected during orbital operation.

3.4.1 Channel Spectral Response

The channel spectral response bands and their BOL tolerance limits shall be as specified in Table 3.4.1-1.

3.4.2 Spectral Response Stability

The design requirements for the stability of the overall spectral response profile of each channel, between the initially-determined 1% relative response points (RRPs), from the start of Instrument calibration to EOL are as follows:

a. Non-temperature-induced frequency shifts in the 50% RRPs shall not exceed 0.1 cm^{-1}.

b. Over any 1.0 cm^{-1} spectral interval, non-temperature-induced changes in relative response amplitude shall not exceed 0.5 %.

c. Temperature-induced frequency shifts in the 50% RRPs shall not exceed 0.16 cm^{-1}.

d. Over any 1.0 cm^{-1} spectral interval, temperature-induced changes in relative response amplitude shall not exceed 0.2 %.

e. Let the Warm Filter temperature be T_w and the Cold Filter and Detector temperature be T_c. Then for any fixed pair of temperatures T_1 and T_2 in the ranges:

$$60 \text{ K} < T_1 < 80 \text{ K}$$

$$300.0 \text{ K} < T_2 < 302.0 \text{ K}$$

the spectral stability requirements of paragraphs c. and d. above shall be met as temperatures T_w and T_c are simultaneously varied over the following intervals:

$$T_1 - 0.5 \text{ K} < T_c < T_1 + 0.5 \text{ K}$$

$$T_2 - 1.5 \text{ K} < T_w < T_2 + 1.5 \text{ K}$$

3.4.3 Out-of-Band Response

It is a design requirement that for each channel, the ratio of the integrated out-of-band response (OBR) to the integrated in-band response (IBR) shall not exceed the figure given in the "Out of Band Response Ratio" column of Table 3.4.3-1, where the OBR is integrated over the spectral interval 350 cm^{-1} to 2140 cm^{-1} but excluding the interval between the 0.2% relative response points, and the IBR is integrated over the spectral interval between the 5% relative response points. This requirement shall apply when the Instrument is viewing either the atmosphere, within the atmospheric sounding range, or the IFC black body. This requirement shall be verified by analysis, and by test to the extent practicable.

3.4.4 Radiometric Performance

3.4.4.1 [Deleted]

3.4.4.2 Radiometric Channel Gain

In the following requirements, it is assumed that the Instrument is operating normally with a chopper reference target at a temperature of ≤ 100 K.

a. The analog gain of each radiometric channel, between the entrance aperture and the quantizer input, shall be set so that when the Instrument is viewing a scene having the "Maximum Expected In-Orbit Input Radiance" value given in Table 3.4.1-1, the quantizer digital output values shall be within the range of 50 % to 80 % of the positive and negative full scale values, assuming a symmetrical bipolar range and zero dc offset at the input to the quantizer.

b. The overall gain of each radiometric channel, from the entrance aperture to the telemetry output, shall be set so that when the Instrument is viewing a scene having the "Maximum Expected In-Orbit Input Radiance" value given in Table 3.4.1-1, the telemetry output shall have a mean value between 44000 and 50000, assuming a 16-bit unsigned linear representation and no offset.

3.4.4.2.1 Radiometric Channel Gain Stability

The overall gain of each radiometric channel, between the scan mirror and the quantizer output, determined with a measurement bandwidth of 42 Hz, shall change by not more than 2 parts in 1E4 over any time period up to 10 s, and by not more than 1 part in 1E3 over any 66 s period. For the purposes of this requirement, scan-angle-dependent changes in optical throughput may be ignored. This requirement shall be met over the dynamic range of each channel as defined in Section 3.4.6.

3.4.4.3 Radiometric Channel Offset

The telemetry output of each radiometric channel shall include a commandable offset. The commandable range of this offset, when the demodulated radiance signal is zero, shall be at least zero to half scale of the telemetry output in increments no greater than 100 output quantization levels.

3.4.4.3.1 Radiometric Channel Offset Stability

The change in radiometric offset in any channel over any 10-second time period when viewing a full-aperture, constant-radiance source shall not exceed 30% of the NEN value given in the "Radiometric Noise" column of Table 3.4.1-1. This requirement shall be met for any input radiance within the dynamic range of each channel as defined in Section 3.4.6.

3.4.4.4 End-to-End Channel Transfer Function

The pre-calibration radiometric transfer function of each channel, from the entrance pupil to the telemetry output and over the dynamic range specified in Section 3.4.6, shall be such that the input radiance corresponding to a given telemetry output value does not deviate from the expected input radiance for that output value by more than ±20% of the input radiance, or by the radiance difference corresponding to a Planckian black body temperature uncertainty of ±3.0 K, whichever is greater. For the purpose of this requirement, the "expected input" shall be interpreted as that inferred from the product of the transfer functions of the contributing subsystems, each of which shall have been previously verified against the relevant subsystem specification.

3.4.4.5 Electrical Crosstalk between Radiometric Channels

The telemetry output of any "receptor" channel shall not change by more than the greater of 1 quantization level or 0.02% of the value corresponding to the Maximum Expected Input Radiance listed in Table 3.4.1-1, as the signal level in any "donor" channel is varied over its full dynamic range as defined in Section 3.4.6.

[Intentionally Blank]

Channel Number	Species	Lower 50% Response Point cm^{-1}			Upper 50% Response Point cm^{-1}			Desired Response λ (Ref.) μm		Maximum Expected In-Orbit Input Radiance W•m^{-2}•sr^{-1}	BOL Radiometric Noise * 10^{-4} W•m^{-2}•sr^{-1}
		Low Limit	Desired	High Limit	Low Limit	Desired	High Limit	Lower	Upper		
1	N_2O, aerosol	561.50	563.00	565.50	586.25	588.00	588.25	17.01	17.76	3.90	10.2
2	CO_2	598.50	600.00	602.50	613.75	615.00	615.75	16.26	16.67	2.34	5.5
3	CO_2	607.00	610.00	613.00	637.50	640.00	641.50	15.63	16.39	4.66	5.1
4	CO_2	623.00	626.00	629.00	657.00	660.00	663.00	15.15	15.97	5.25	5.2
5	CO_2	652.00	655.00	658.00	677.00	680.00	683.00	14.71	15.27	3.82	3.7
6	aerosol	819.20	821.00	823.80	832.60	836.00	837.40	11.96	12.18	2.27	1.6
7	$CFCl_3$	832.60	835.00	837.40	849.60	853.00	854.40	11.72	11.98	2.60	1.7
8	HNO_3	859.00	860.00	864.00	901.00	905.00	906.00	11.05	11.63	6.27	3.6
9	CF_2Cl_2	913.40	915.00	918.60	928.90	933.00	934.10	10.72	10.93	2.31	1.7
10	O_3	988.20	990.00	993.80	1006.20	1010.00	1011.80	9.90	10.10	2.02	1.3
11	O_3	1008.10	1011.00	1013.90	1043.60	1048.00	1049.40	9.54	9.89	3.53	2.1
12	O_3	1116.80	1120.00	1123.20	1135.30	1140.00	1141.70	8.77	8.93	1.56	0.8
13	aerosol	1198.60	1200.00	1205.40	1216.60	1220.00	1223.40	8.20	8.33	1.30	0.9
14	N_2O_5	1227.50	1229.00	1231.50	1258.75	1260.00	1260.75	7.94	8.14	1.86	0.9
15	N_2O	1255.25	1256.00	1257.25	1280.75	1282.00	1282.75	7.80	7.96	1.47	0.9
16	$ClONO_2$	1277.25	1278.00	1279.25	1297.75	1299.00	1299.75	7.70	7.82	1.13	0.9
17	CH_4	1321.70	1324.00	1329.30	1363.70	1369.00	1371.30	7.30	7.55	2.09	1.0
18	H_2O	1383.00	1385.00	1391.00	1431.00	1435.00	1439.00	6.97	7.22	1.97	1.0
19	aerosol	1401.25	1402.00	1403.25	1414.75	1416.00	1416.75	7.06	7.13	0.55	1.1
20	H_2O	1417.90	1422.00	1426.10	1537.70	1542.00	1546.30	6.49	7.03	3.90	1.4
21	NO_2	1581.00	1582.00	1590.00	1625.90	1634.00	1635.10	6.12	6.32	1.17	0.9

* These values assume an effective bandwidth of 7.5 Hz, which is the nominal bandwidth for the Global Mode.

Table 3.4.1-1 Spectral Channels

Channel Number	Species	Atmospheric Sounding Range* (km)	Minimum Space View† (km)	Out-of-Band Response Ratio
1	N_2O, aerosol	8–70	75	1.2E-4
2	CO_2	8–40	95	2.0E-4
3	CO_2	8–60	125	3.9E-4
4	CO_2	15–60	140	4.4E-4
5	CO_2	30–105	150	3.2E-4
6	aerosol	8–55	65	9.4E-6
7	$CFCl_3$	8–50	60	1.2E-5
8	HNO_3	8–70	65	2.7E-5
9	CF_2Cl_2	8–50	65	1.2E-5
10	O_3	8–55	100	1.5E-5
11	O_3	30–85	105	2.9E-4
12	O_3	8–55	80	3.8E-5
13	aerosol	8–55	65	6.8E-6
14	N_2O_5	8–60	70	1.8E-5
15	N_2O	8–70	75	1.7E-5
16	$ClONO_2$	8–70	75	1.5E-5
17	CH_4	8–80	75	2.3E-5
18	H_2O	8–40	75	1.2E-5
19	aerosol	8–55	65	6.4E-6
20	H_2O	15–85	75	4.3E-5
21	NO_2	8–70	70	1.4E-5

* These ranges represent the tangent heights over which useful retrievals will be possible, plus an additional 15 km at the upper boundary, which is required for the retrieval process.

† These minimum heights do not include the additional 10 km required by IRD Section 2.7.1.

Table 3.4.3-1 Critical Atmospheric Tangent Heights

3.4.4.5.1 Electrical Crosstalk under Test Overload

For test and calibration purposes, the signal processing chain from the detector output to the telemetry output, including the detector bias circuits, shall be designed to allow an optical input overload on any single channel equivalent to viewing a source radiance 1.0E+3 times that of a 300 K black body, while affecting the telemetry output of all non-overloaded channels, assumed to be viewing a constant radiance, by no more than the greater of the output rms noise level or 1 telemetry quantization level.

3.4.4.6 Radiometric Channel Overload Recovery

Each radiometric channel, between the photon input to the detector and the digitizer output, shall be able to operate within all specifications within 12 chopper cycles following the removal of an overload condition corresponding to an input scene radiance of up to twice the dynamic range maximum defined in Section 3.4.6. This requirement shall be met for overloads of any duration and occurring in any number of channels simultaneously.

3.4.4.7 Radiometric Channel Slew Rate

The signal processing electronics shall support a slew rate r_s of the detected radiometric signal, from the preamplifier input to the quantizer output, of not less than

$$r_s = f_c \bullet 0.1 \bullet n_{max}$$

where: r_s = slew rate in quantization levels per second
f_c = chopping frequency in Hz
n_{max} = steady-state output value corresponding to the dynamic-range-maximum input radiance specified in Section 3.4.6

3.4.5 Radiometric Noise

3.4.5.1 End-to-End Radiometric Noise Performance

For each channel the Noise Equivalent Radiance (NEN) of the signal path from the entrance pupil to the telemetry output, assuming a 7.5 Hz bandwidth, shall be less than or equal to that specified in the BOL Radiometric Noise column in Table 3.4.1-1.

For the purposes of this requirement, NEN is defined as the increase in scene radiance, within the spectral band of a channel, that causes an increase in the mean value of the output data equal to the standard deviation of the output data.

This requirement shall apply over a temperature range of 60 K to 65 K at the focal plane assembly.

3.4.5.2 Noise-Equivalent Power

For each channel, the NEP´, as measured at the telemetry output, for infrared radiation incident on the focal plane, at a modulation frequency of 500 Hz and at a detector operating temperature of 65 K, shall be no greater than the value shown in Table 3.4.5.2-1.

Determination of NEP´ shall include the background photon noise.

Channel	NEP´ (nW/√Hz)
1	3.43E-04
2	2.47E-04
3	2.78E-04
4	2.83E-04
5	2.29E-04
6	1.58E-04
7	1.69E-04
8	4.75E-04
9	2.06E-04
10	1.49E-04
11	2.67E-04
12	7.27E-05
13	1.03E-04
14	1.03E-04
15	1.16E-04
16	1.07E-04
17	1.22E-04
18	1.14E-04
19	8.93E-05
20	1.76E-04
21	1.18E-04

Table 3.4.5.2-1 Channel NEP´

3.4.6 Channel Dynamic Range

Except as otherwise stated, the “dynamic range” of each radiometric channel shall mean the range of channel signal levels corresponding to scene radiances from ~0 (cold space view) to 1.25 times the radiance value for that channel given in the “Maximum Expected In-Orbit Input Radiance” column of Table 3.4.1-1.

3.4.7 Radiometric Digitization

3.4.7.1 [Deleted]

3.4.7.2 Radiometric Quantization Step Size Uniformity

The radiometric signals must be quantized with a resolution of one part in 2^{16}, and the step size must be uniform to within $\Delta / 2$ (where Δ is the quantization step size).

3.4.7.3 Sampling Rates

3.4.7.3.1 Raw Data Sampling Rate

The detector outputs of all spectral channels shall be sampled twice per cycle of the optical chopping waveform. Sampling shall occur at a phase delay with respect to the optical chopping waveform that is separately programmable for each channel.

3.4.7.3.2 Radiometric Sampling Rate

The effective radiometric sampling rate for a spectral channel is the rate at which radiometric data for that channel are output to the Science Data telemetry stream.

In the Global Mode, the radiometric sampling rate for all channels shall be 1/6 of the chopping frequency. Programming flexibility shall allow the allocated telemetry bandwidth to be used for a subset of the spectral channels, sampled at a higher rate.

3.4.8 Radiometric Signal Processing

The Instrument shall provide programmable processing of the detector output samples that includes, as a minimum, quantization, synchronous demodulation and digital filtering.

3.4.8.1 [Deleted]

3.4.9 In-Flight Radiometric Calibration

The in-flight calibration shall be established using space views and the view of an on-board blackbody source. For each channel the space view shall be at or above the minimum tangent height given in Table 3.4.3-1, and via the same optical train used for normal atmospheric scanning. The blackbody view shall be via the same optical train used for normal atmospheric scanning with the addition of one fixed, temperature-controlled mirror between the blackbody source and the scan mirror.

3.4.9.1 In-Flight Calibration Mirror

The IFC mirror shall meet the following thermal performance requirements:

a. Range: The temperature of the IFC mirror shall be controllable by the IPS to any setpoint in the following range: {the minimum natural equilibrium temperature or 10 °C, whichever is higher} to {45 °C}.

b. Control Accuracy: The temperature control function shall be capable of holding the mean temperature of the mirror reflective surface to within ±0.5 K of the setpoint under on-orbit environmental conditions.

c. Temperature Uniformity: The maximum temperature difference between any two points on the mirror reflective surface shall not exceed 1.0 K.

d. Temperature Knowledge: Temperature sensors shall be used to provide knowledge of the mean temperature of the mirror reflective surface with an absolute accuracy of ±0.5 K and a measurement resolution of 0.02 K or less.

e. Temperature Stability: After reaching thermal equilibrium at any fixed setpoint within the range specified in paragraph a above, fluctuations in the mean temperature of the mirror reflective surface shall not exceed a rate of 0.07 K/min.

3.5 Pointing and Scanning Specifications

The Instrument shall make measurements of optical bench rotation (relative to inertial space) and scan mirror orientation (relative to the optical bench) in order to allow the position in the atmosphere which corresponds to given radiance samples to be determined in ground processing.

The pointing and scanning specifications make use of the following definitions:

a. The term **systematic error** refers to unknown transfer function characteristics that depend upon parameters such as angle (e.g. encoder non-linearity) or temperature, but have no explicit time dependence over measurement times of interest.

b. The term **random error** refers to zero-mean stochastic error, band limited by passage through the PLPF.

c. The term **pointing low-pass filter** (PLPF) refers to a hypothetical filter representing the characteristics of the instrument low-pass filters in the gyro and scanner angle signal processing channels. It is formally defined to be an 8-pole Butterworth-type low-pass filter with the corner frequency set at 36 Hz.

d. The term **pointing** refers to the spectrum of angular motion obtained by multiplying the rms spectrum of the actual motion by the normalized PLPF characteristic defined in c. above.

e. The term **jitter** refers to the spectrum of angular motion obtained by subtracting from the rms spectrum of the actual motion the "pointing" spectrum defined in d. above.

f. Let the radiometric channel low-pass filter characteristic, including both positive and negative frequencies, be repeated by convolution with a series of Dirac delta functions centered at the fundamental and the higher harmonics of the chopping frequency; then **in-band jitter** is defined as the angular motion spectrum obtained by multiplying the "jitter" spectrum (defined in e. above) by this repeated filter characteristic.

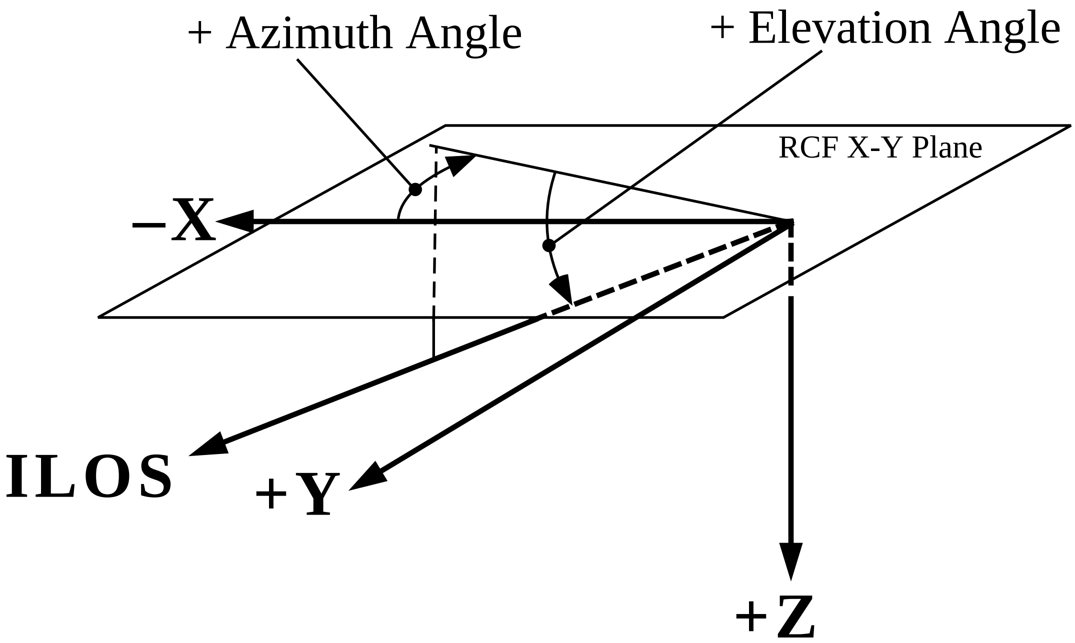
g. The term **synchronous jitter** is defined as that portion of the "in-band jitter" spectrum (defined in f. above) lying within ±0.1 Hz of the fundamental or higher harmonics of the chopping frequency.

h. The terms **elevation angle** and **azimuth angle** in some Reference Coordinate Frame (RCF) for a given ILOS are defined in Figure 3.5-1. Different angles may result depending on whether the reference coordinate frame is the TRCF, the IRCF, or the SRCF as defined in Section 3.1.3. It should be noted that the elevation and azimuth ILOS angles relative to the TRCF are not, in general, equal to twice the scanner elevation and azimuth shaft angles.

i. The **channel instantaneous line-of-sight** is defined as the ray from the center of a specified channel field stop, projected through the center of the system aperture stop, via the scan mirror towards the atmosphere.

j. The term **relative elevation angle** is defined as the difference in elevation angle of any **channel instantaneous line-of-sight**, in some specified coordinate system, between specified scanner angle measurement sets; **relative azimuth angle** is similarly defined for azimuth angles.

k. The term **sample** is defined as a set of simultaneously-acquired data from the Scanner and Gyro subsystems which, after applying appropriate calibration corrections, and averaging appropriate to the desired measurement bandwidth, implies an ILOS with respect to inertial space.



Note: The Azimuth Angle is the angle between RCF –X axis and the projection of the ILOS on the RCF X-Y plane.

The Elevation Angle is the angle between the projection of the ILOS on the RCF X-Y plane and the ILOS.

Figure 3.5-1 ILOS Angle Definitions

3.5.1 Elevation Pointing and Scanning

3.5.1.1 Elevation Scan Range

The boresight placement accuracy and ILOS scan range requirements are given in Table 3.5.1.1-1.

Parameter	Elevation
Boresight-to-IRCF	25.3°± 300"
ILOS Scan Range (relative to Boresight)	–3.22° +2.03°

Table 3.5.1.1-1 Boresight and ILOS Elevation Scan Range

3.5.1.2 Elevation Scan Rate

3.5.1.2.1 Elevation Shaft Angle Rate and Settling Time

The following requirement shall be verified in the absence of optical bench external vibrations:

The scanner shall be capable of moving the scan mirror in elevation at constant shaft angle rates from –0.5 °/s to +0.5 °/s adjustable with a resolution of 0.005 °/s or less. After a rate transition with no reversal of direction, the elevation shaft angle rate, smoothed by the PLPF shall settle to within ±10% of the new commanded rate or to the new commanded rate ±5E-4 °/s, whichever is the wider tolerance, within 0.1 s.

3.5.1.2.2 ILOS Elevation Angle Rate

The following requirement shall be met in the on-orbit thermal and vibrational environments specified in Sections 3.11.6 and 3.11.7:

During a nominally constant-rate vertical scan segment of duration up to 10 s, after a settling period of 0.2 s following an elevation rate change, the ILOS scan rate relative to the TRCF, and smoothed by the PLPF, shall not vary by more than ±0.015 °/s for rates of magnitude 0.3 °/s and above. For rates of magnitude 0.01 °/s to 0.3 °/s, the ILOS scan rate relative to the TRCF and smoothed by the PLPF shall vary by no more than ±5% of the rate.

3.5.1.2.3 Elevation Scan Programmability

The scanner shall be capable, by command from the IPU, of moving the scan mirror in elevation at constant shaft angle rates from –0.5 °/s to +0.5 °/s adjustable with a resolution of 0.005 °/s or less.

The elevation shaft angle rate shall be programmable, with the capability of executing up to four constant-rate segments within a single elevation scan (constant direction of motion).

3.5.1.3 [Deleted]

3.5.1.4 Fixed Angle Mode

To facilitate testing in a laboratory environment, the Instrument shall be capable of holding, by IPS command, a fixed LOS elevation angle in the TRCF (as defined in Figure 3.5-1):

a. repeatable to within 0.025° (90 arcsec), after a settling time of 1.0 s, for any commanded elevation shaft angle within the elevation scan range, assuming all relevant temperatures have remained within, or returned to, ranges of 5 °C or less

b. commandable in increments of 2 arcsec or less

c. with a mean value, averaged over any 1 minute period, that is constant to within 4 arcsec relative to any other stationary setting within the previous 60 minutes of time, assuming that all relevant temperatures have remained within ranges of 1 °C or less

3.5.1.5 Elevation Angle Jitter

Note: See definitions in Section 3.5.

This requirement shall be met in the on-orbit thermal and vibrational environments specified in Sections 3.11.6 and 3.11.7.

The elevation angle jitter shall not exceed the levels defined by the allowable elevation angle single-sided power spectral density (PSD) requirement plotted in Figure 3.5.1.5-1, and defined numerically in Table 3.5.1.5-1. This requirement shall be met over the elevation and azimuth angle ranges defined in Sections 3.5.1.1 and 3.5.2.1, respectively. LOS Displacement is defined as the difference between the instantaneous LOS elevation angle, relative to inertial space, in the presence of jitter sources and in the absence of jitter sources. This requirement applies to both broadband *random jitter* and *periodic jitter* components for frequencies above 36 Hz.

For the purpose of demonstrating compliance with this requirement, the effective resolution bandwidth used for measuring the PSD of the LOS jitter shall be less than or equal to 20 Hz, except for frequencies lying within ± 40 Hz of the fundamental or higher harmonics of the chopping frequency, in which case the effective resolution bandwidth shall be equal to or less than 5 Hz.

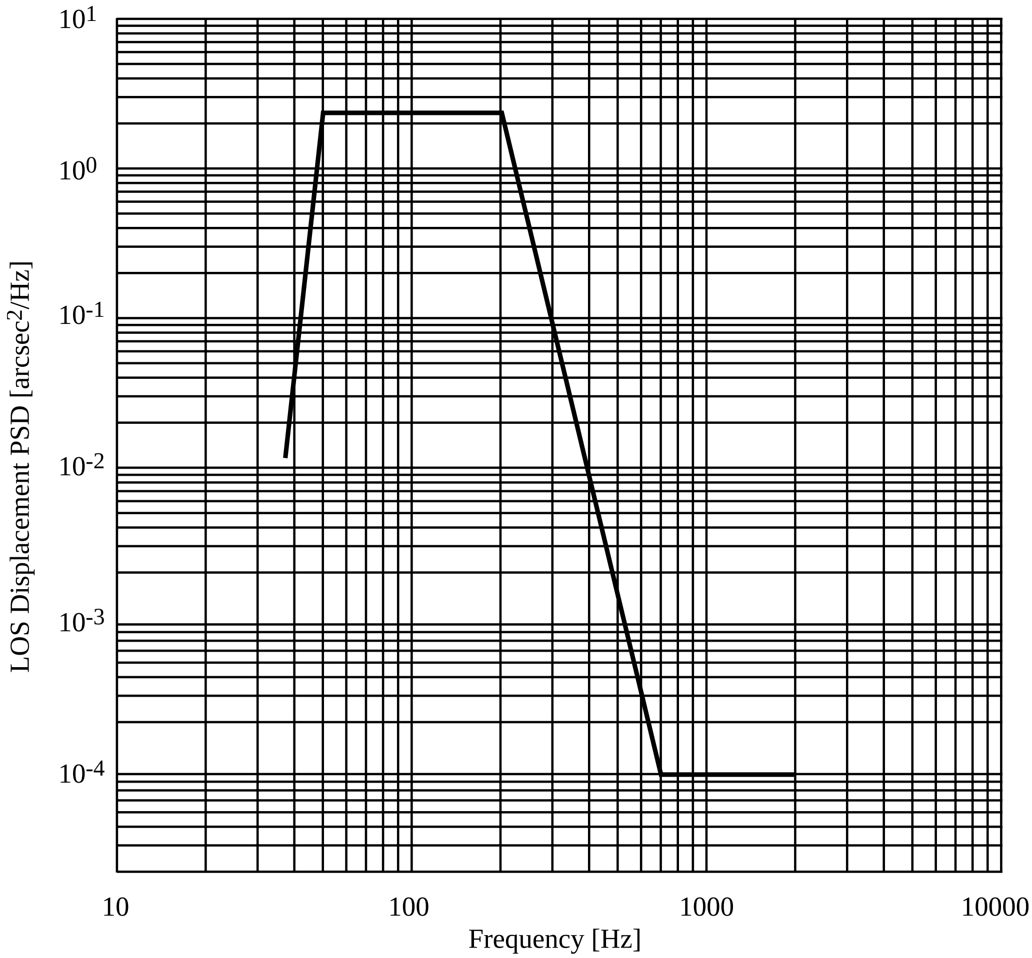


Figure 3.5.1.5-1 LOS Jitter PSD Requirement

Frequency Hz	PSD arcsec^2/Hz	Slope dB/decade
36	1.17E-2	
36-50		+160
50-200	2.24	
200-700		-80
700-2000	9.94E-5	

Table 3.5.1.5-1 Numerical Data for Figure 3.5.1.5-1

3.5.2 Azimuth Pointing and Scanning

3.5.2.1 Azimuth Scan Range

The boresight placement accuracy and ILOS scan range requirements are given in Table 3.5.2.1-1.

Parameter	Azimuth
Boresight-to-IRCF	0°± 0.1°
ILOS Scan Range*	+21.0° –43.0°

*Note: This is the scan range for viewing outside the Instrument enclosure, it specifically does not include viewing the IFC.

Table 3.5.2.1-1 Boresight and ILOS Azimuth Scan Range

3.5.2.2 Azimuth Scan Step and Settle

See Section 4.4.10.3.1.

3.5.2.3 Azimuth Pointing Accuracy

The following requirement shall be met over the dynamic and thermal environments specified in Sections 3.8 and 3.11:

For any commanded elevation and azimuth shaft angles corresponding to ILOS directions within the atmospheric scan range, the unsigned difference between the actual ILOS azimuth angle and the ILOS azimuth angle calculated from the scanner sensor outputs and TSS calibration data, relative to the TRCF, shall not exceed 72 arcsec during any time period between 2.0 s and 10 s following the initiation of an azimuth step of any magnitude up to 7.5 ° shaft angle.

3.5.2.4 Azimuth Angle Knowledge

The following requirement shall be met over the dynamic and thermal environments specified in Sections 3.8 and 3.11:

For any two Global Mode vertical scans (of approximately 10s duration each) separated in time by any interval in the range of 10 s to 66 s, or by any interval in the range of p–132 s to p+132 s, where p is the orbital period, the difference between the mean ILOS azimuth angle during the first vertical scan and the mean ILOS azimuth angle during the second vertical scan, relative to inertial space, shall be known with an unsigned error not exceeding 144 arcsec. These means shall be taken over the full duration of the vertical scans, excluding 1.0 s of settling time following the initiation of any azimuth step of up to 7.5 ° shaft angle. This requirement shall apply where the two vertical scans are taken at any two fixed azimuth shaft angle settings corresponding to ILOS azimuth angles within the azimuth scan range specified in Table 3.5.2.1-1.

3.5.3 Instrument Alignment

3.5.3.1 Interface Alignment Cube

The Instrument shall contain an optical cube, defined as the Interface Alignment Cube (IAC). The IAC shall be attached to the baseplate in accordance with the HSICD Sections 3.5.1 and 3.5.2. The IAC shall meet the requirements in GIRD Section 3.5.2. Alignment parameters and responsibilities shall be in accordance with GIRD Sections 3.5.3 and 3.5.4. The measured angles between the IAC and the Instrument boresight shall be documented in accordance with GIRD Section 3.5.5.

3.5.3.2 TRCF-to-IRCF Alignment

The equilibrium position in orbit of the TRCF relative to the IRCF shall be within the limits shown in Table 3.5.3.2-1 over the operational lifetime of the instrument.

Rotation about IRCF Axis:	X	Y	Z
Max. TRCF to IRCF Misalignment, arcsec:	204	240	204

Table 3.5.3.2-1 TRCF-to-IRCF Alignment Allocation

3.5.3.3 Optical Cube Requirements

Optical cube requirements shall be in accordance with GIRD Section 3.5.1.

3.5.3.3.1 Optical Cube Surface Area

Optical cubes shall have a per-face surface area of at least 360 mm^2.

3.5.3.3.2 Optical Cube Surface Orthogonality

Unless otherwise stated herein, optical cubes surfaces shall meet the orthogonality requirements of GIRD Section 3.5.1.2.

3.5.3.3.3 Optical Cube Documentation

The location of the IAC shall be provided to the Spacecraft Contractor for documentation in the HSICD.

3.5.3.3.4 Optical Cube Cover

A flight-quality, removable, protective and retaining cover shall be installed over each optical alignment cube prior to launch. The IAC shall be covered at all times, except when in use.

3.5.4 Baseline Scan Patterns

Verification of scanner functionality shall include successful execution of the baseline scan pattern defined in SP-HIR-198, Table 1.

3.6 Mechanical Specifications

3.6.1 Instrument Envelope

The Instrument shall be contained within the envelope defined in the UIID Figure 3-2. The Instrument envelope shall be provided to the Spacecraft Contractor for documentation in accordance with GIRD Section 3.1.3. Instrument fields of view allocation shall be in accordance with GIRD Section 3.2.1.

3.6.2 Instrument Mass Properties

3.6.2.1 Mass

The mass of the Instrument shall not exceed the Total specified in Table 5.1-1. The mass shall be measured to ±0.1 kg and the measured value shall be provided to the Spacecraft Contractor for documentation in accordance with GIRD Section 3.3.2.

3.6.2.2 Center of Mass Measurement

The sunshield-closed and sunshield-open centers of mass of the Instrument shall be measured and reported to ± 5 mm, referenced to the IRCF.

3.6.2.3 Moments of Inertia

Moments of inertia shall be determined to an accuracy of ± 10%. The moments of inertia for the sunshield-open and sunshield-closed conditions of the Instrument, referenced to the Instrument origin, shall be documented in accordance with GIRD Section 3.3.4.3.

3.6.3 Mechanical Interface with Spacecraft

3.6.3.1 Instrument Mounting

The Instrument and the Mechanical GSE shall be designed to allow the Instrument to be mounted to, or removed from, the Spacecraft with the Z-axis vertical; +Z up.

Mounting or removal of the Instrument to/from the Spacecraft shall not require the removal of other instruments or instrument components.

3.6.3.1.1 Mounting Interface

The Instrument-to-Spacecraft mounting interface shall be designed and documented in accordance with the requirements of GIRD Section 3.4. The Instrument shall be mechanically attached to the Spacecraft by an interface consisting of coplanar mounting pads located in positions to be proposed by the Instrument Provider and approved by the Spacecraft Contractor. Any required "kinematic" hardware between the mounting pads and the Spacecraft structure will be provided by the Spacecraft Contractor per GIRD Section 3.4.3.2. If other than a 3-mount kinematic interface is proposed, it shall be demonstrated by analysis that the worst-case static loads and resulting distortions of both the instrument and spacecraft sides of the interface are within acceptable limits, the limits on the spacecraft side to be defined by the Spacecraft Contractor.

3.6.3.1.2 Instrument Drill Templates

Instrument interfaces shall be drilled using templates to correctly establish the mounting hole patterns. A template shall be provided to the Spacecraft Contractor for the Instrument-to-Spacecraft interface in accordance with GIRD Section 3.4.5.3. The template fabrication requirements will be provided by the Spacecraft Contractor in accordance with GIRD Section 3.4.5.2

3.6.3.1.3 [Deleted]

3.6.3.2 Limit Loads

Interface Design Limit Loads shall meet the requirements of GIRD Section 3.6.3.

Limit loads shall be based on the requirements of GIRD Section 3.6.3.3 and shall be applied at the Center of Mass of the Instrument as configured for launch. The loads shall be applied in one direction in such a way as to produce the maximum stresses at the interfaces.

3.6.3.2.1 Factors of Safety

Ultimate and yield design limit load factors of safety shall meet the requirements of GIRD Section 3.6.3.3.1.

3.6.3.2.2 Qualification Loads

Qualification loads shall meet the requirements of GIRD Section 3.6.3.3.2.

3.6.3.2.3 Strength of Materials

The Instrument shall be designed to withstand qualification acceleration levels without experiencing any rupture, buckling, material failures or permanent deformation. Calculations shall be based on the minimum material condition.

3.6.3.3 Disturbance Torques

Instrument induced constant disturbance torques shall meet the requirements of GIRD Section 3.10.1. Instrument induced periodic disturbance torques shall meet the requirements of GIRD Section 3.10.2. Disturbance torques limits for linear forces shall be in accordance with GIRD Section 3.10.3 Angular momentum reacted from the Instrument to the Spacecraft shall meet the requirements of GIRD Section 3.10.5.1.

The actual instrument torque versus time profile shall be provided to the Spacecraft Contractor for documentation in accordance with GIRD Section 3.10.4.

3.6.3.3.1 Sunshield Door Disturbance

Motion of the Sunshield Door shall not create dynamic disturbances that prevent the Instrument from acquiring uncorrupted Science Data continuously during changes of door position.

3.6.4 Instrument Structural Dynamics

The Instrument shall be designed with sufficient stiffness to ensure that the overall pointing and stability requirements of Section 3.5 are met. The Instrument, configured for launch, shall have a fixed-based frequency in accordance with the requirements of GIRD Section 3.6.2.1.

3.6.5 Pressurized System Design

Requirements for the design of pressurized systems shall be as defined in GIRD Section 3.6.5.

3.6.6 Instrument Mechanisms

3.6.6.1 [Deleted]

3.6.6.2 Caging of Mechanisms

All mechanisms which require restraint during launch shall be caged without requiring power, per the requirements of GIRD Section 3.9. Mechanisms which require caging during test and launch site operations shall meet the requirements of GIRD Section 3.9.1.

3.6.6.3 Drive Mechanism Torque Margin

Each drive mechanism shall meet the torque ratio requirements specified in Section 3.4.5.3 of the MAR (GSFC 424-11-13-01).

3.6.6.4 Drive Motor Locked-Rotor Survival

Any motor whose body outer temperature could rise by more than 20 K, in air or vacuum, if continuously powered at the maximum available driver current under locked rotor conditions shall:

a) be fitted with a temperature sensor, the output of which is read by the IPU, and is included in the Engineering Telemetry stream

b) be capable of being powered down by the IPU upon detection of a body temperature exceeding a stored setpoint, a separate setpoint being stored for each such motor

c) be designed to survive, in air or vacuum, without damage or performance degradation, the power dissipation occurring during a period of continuous excitation at maximum drive current and with locked rotor from initial power-on to the removal of power by the IPU as described in b) above.

Drive motors and mechanisms shall not be damaged by any available shutdown sequence.

3.6.7 Access to Instrument Components

Access requirements shall be in accordance with GIRD Section 3.11. Removable parts must be keyed or pinned to assure proper re-assembly and re-alignment.

3.6.8 [Deleted]

3.6.9 Launch Site Equipment Installation and Removal

All items to be installed, removed, or replaced at the Spacecraft integration level shall employ captive hardware per GIRD Section 3.9.2. All items to be installed or removed prior to flight shall be tagged per GIRD Section 3.16.

3.7 Electrical Specifications

3.7.1 Electrical Interface with Spacecraft

The Instrument shall meet all requirements of GIRD Section 5 and applicable subsections thereof, as modified by the HIRDLS UIID and the HSICD.

3.7.1.1 Power Buses

The power bus requirements of GIRD Section 5.1.2 shall be interpreted to mean that each redundant power supply bus will be individually switched on the Spacecraft side of the Instrument/Spacecraft interface. Instrument startup shall be facilitated by an appropriate part of the Instrument electronics being active whenever HIRDLS Quiet Bus A or Quiet Bus B power is on. The Instrument need not perform within specifications, but shall suffer no permanent degradation if both buses are powered simultaneously for an indefinite period.

3.7.1.1.1 [Deleted]

3.7.1.1.2 [Deleted]

3.7.1.1.3 [Deleted]

3.7.2 Power Specifications

The Instrument shall operate within specifications when furnished with spacecraft power having the characteristics specified in GIRD Section 5.2 and applicable subsections thereof, as modified by the HIRDLS UIID and the HSICD.

3.7.2.1 [Deleted]

3.7.2.2 [Deleted]

3.7.2.3 [Deleted]

3.7.2.4 [Deleted]

3.7.2.5 [Deleted]

3.7.2.6 Abnormal Operation

The Instrument shall sustain no damage or permanent performance degradation due to any of the following abnormal conditions:

a. Unannounced removal of power from any bus or combination of buses.
b. Polarity reversal on any bus or combination of buses.
c. Undervoltage or overvoltage conditions, within the limits specified in the applicable documents, on any bus or combination of buses.
d. Loss of continuity on one side (power or return) of any bus or combination of buses.

3.7.2.7 [Deleted]

3.7.2.7.1 [Deleted]

3.7.2.7.2 [Deleted]

3.7.2.7.3 [Deleted]

3.7.3 Grounding & Isolation

3.7.3.1 [Deleted]

3.7.3.2 Primary Power Isolation

Isolation between any primary power line and any secondary power line shall be greater than 1 MΩ and less than 1 μF.

3.7.3.3 Secondary Power Grounding and Isolation

The subsystem structures shall not be used as intentional power return conductors. Structures shall not be used as intentional signal returns at the spacecraft interface.

The secondary power and signal grounds must be connected to the structure ground at one point only. When the single secondary power ground connection is removed, the isolation between secondary power and the structure shall be greater than 1 MΩ and less than 1 µF.

3.7.3.4 [Deleted]

3.7.3.5 [Deleted]

3.7.3.6 Bonding

The subsystems direct or indirect bonding methods shall achieve an RF impedance of 500 mΩ or less at a frequency of 1.0 MHz.

3.7.3.6.1 Equipment Bonding

The bonding procedures and methods of MIL-B-5087, Class R and MIL-STD-889 shall be used for design implementation.

3.7.3.6.2 Electrical Connector Bonding

Connector mounting surfaces on all units and assemblies shall be free from paint or other non-conducting material. The dc resistance between electrical interface receptacle shells and their parent unit housing shall not exceed 2.5 mΩ for multi-pin connectors and 5.0 mΩ for coaxial connectors.

3.7.4 [Deleted]

3.7.4.1 [Deleted]

3.7.4.2 [Deleted]

3.7.5 [Deleted]

3.7.5.1 [Deleted]

3.7.5.2 [Deleted]

3.7.5.3 [Deleted]

3.7.5.4 [Deleted]

3.7.5.5 [Deleted]

3.7.5.6 [Deleted]

3.7.5.7 [Deleted]

3.7.6 EMI/EMC Specifications

The Instrument shall meet all electromagnetic compatibility and magnetic requirements defined in GIRD Section 10.11 and the subsections thereof as modified by the UIID and the HSICD.

3.7.6.1 [Deleted]

3.7.6.2 [Deleted]

3.7.6.3 [Deleted]

3.7.6.4 [Deleted]

3.7.6.4.1 [Deleted]

3.7.6.4.2 [Deleted]

3.7.6.4.3 [Deleted]

3.7.6.5 [Deleted]

3.7.6.6 [Deleted]

3.7.6.7 [Deleted]

3.7.6.8 [Deleted]

3.7.6.9 [Deleted]

3.7.7 Temperature Sensors

Provision shall be made for monitoring operational temperatures throughout the Instrument. Except where a higher accuracy is specified, it shall be possible to infer from the telemetry data stream, after application of the specified response equation, the temperature of each operational temperature sensor with at least the absolute accuracy and resolution values given in Table 3.7.7–1.

Group	Function	Range ℃	Accuracy K	Resolution mK
1	Radiometric Temperatures (optical bench, mirrors, etc.)	–25 to –5 –5 to +35 +35 to +55	±0.75 ±0.5 ±0.75	20 5 20
2	Engineering Temperatures (structure, electronics, mechanisms, etc.)	–80 to –10 –10 to +40 +40 to +80	±1.50 ±1.00 ±1.50	150 50 150

Table 3.7.7-1 Operational Temperature Sensing Requirements

Temperature sensors shall be chosen from the following types:

(a) GSFC-311P18-02 (YSI 44902) [2252 Ω @ 25° C]

(b) GSFC-311P18-08 (YSI 44908) [10.0 kΩ @ 25° C]

(c) Analog Devices Type AD590 [1 µA per K]

(d) Special devices such as PRTs for applications requiring performance/stability characteristics not available from types (a) through (c).

3.7.8 Survival Heaters

A minimum survival temperature shall be identified for each subsystem. Minimum survival temperature is defined as the minimum cold-start temperature for reliable, operational performance, but not necessarily within operational specifications. For structural items, minimum survival temperature is defined as the minimum temperature for surviving without permanent degradation.

Individual, thermostat-controlled heaters shall be sized and located, and set-points determined, such as to ensure instrument survival for an indefinite period while the spacecraft is in the survival orientation as defined in the HSICD, Table 4.3.3-1. The power dissipation in the ON state of each separately controlled heater shall not exceed that which would raise the local temperature by 10° C during normal instrument operation, in the event of an on-failure of the thermostat switch.

The thermostat setpoint and hysteresis, and the heater power, shall be chosen for each control zone such that no on-off cycling will occur under equilibrium conditions for the expected survival environment.

Two complete sets of survival heaters shall be fitted, each set alone providing the required heat dissipation. One set shall be wired to each of the A and B Survival Heater Buses. The average and peak loads on each Survival Heater bus shall not exceed the Survival Mode allocations given in the UIID.

3.8 Thermal Specifications

3.8.1 Thermal Interface with Spacecraft

All thermal interface requirements with the S/C shall be in accordance with GIRD Section 4.1.

3.8.1.1 Thermal Design

The thermal design of the Instrument shall meet the requirements in GIRD Section 4.2.

3.8.1.2 Heat Transfer

The heat transfer flux averaged at the Spacecraft mechanical interface shall meet the requirements of GIRD Section 4.3.1. Heat producing components shall be separate from sensor assemblies in accordance with GIRD 4.3.2. The Instrument shall be designed for the space environment consistent with the thermal flux design parameters in GIRD Section 4.3.4.

3.8.2 Instrument Temperatures

The Instrument shall meet all performance requirements of this specification over the spacecraft mounting interface temperature range specified in GIRD Section 4.4.1 for all normal operation and survival modes. Temperature limits for the Instrument shall be documented in accordance with GIRD Section 4.4.2. Instrument temperature monitoring shall meet the requirements in GIRD Sections 4.5.2, and 4.5.3.

3.8.2.1 [Deleted]

3.8.3 Thermal Control Hardware

3.8.3.1 Thermal Control Hardware Responsibility

Thermal control hardware shall be provided in accordance with GIRD Section 4.6.2.1 and documented in accordance with GIRD Section 4.6.2.2.

3.8.3.2 [Deleted]

3.9 Command and Data Handling Specifications

The Instrument shall provide the capabilities necessary to accept commands and uploads from the spacecraft and to transmit telemetry to the spacecraft. Instrument command and data handling at the instrument-spacecraft interface shall comply with the requirements given in the following subsections and with all of the applicable requirements in Section 6 of the GIRD as modified by the UIID and the HSICD.

3.9.1 Passive Analog Telemetry

The Instrument shall have redundant temperature sensors that connect to Spacecraft Passive Analog Telemetry channels. As a minimum, these sensors shall be placed at all locations for which minimum survival temperatures have been identified as required in Section 3.7.8 above. Each sensor channel shall conform to the following characteristics:

> Sensor type shall be GSFC-311P18-02 (YSI 44902), [2252 Ω @ 25° C] in parallel with a 5.11 kΩ resistor.

3.9.2 [Deleted]

3.9.3 Command and Telemetry (C&T) Bus Specifications

3.9.3.1 Digital Data Convention

All digital C&T data shall use the following convention:

a. Data words shall be in either 2's complement format with 1 being true, or in unsigned, optionally offset, binary with 1 being true.

b. In serial data transmissions, data bits shall be ordered by significance with the most-significant bit transmitted first.

3.9.3.2 [Deleted]

3.9.3.3 [Deleted]

3.9.3.4 [Deleted]

3.9.3.4.1 [Deleted]

3.9.3.4.2 [Deleted]

3.9.3.5 [Deleted]

3.9.3.5.1 [Deleted]

3.9.3.5.2 [Deleted]

3.9.3.5.3 [Deleted]

3.9.3.5.4 Time Marks and Time Code Data

The Instrument shall implement a safing sequence to be executed in the event that five consecutive time code data packets from the Spacecraft are missed.

3.9.3.6 Telemetry Protocol Specifications

3.9.3.6.1 Engineering Telemetry

The Instrument shall support transmission of an Engineering Telemetry stream as defined in GIRD 6.5.8. The Instrument Engineering Data shall include at least the following parameters:

a. Parameters necessary to determine instrument health and status

b. Status of instrument modes

c. Critical instrument temperatures, voltages, and currents

All engineering telemetry data items, formats, and protocols shall conform to the HSICD.

3.9.3.6.2 Science Telemetry

The Instrument shall support transmitting Science Data to the Spacecraft at rates up to the maximum data rate allocated in the UIID.

All Instrument Engineering Data shall be included in the Science Data stream; this shall be identical to, or a superset of, the Engineering Telemetry defined in Section 3.9.3.6.1.

3.9.3.6.3 Diagnostic Telemetry

The Instrument shall support the output of diagnostic data as defined in GIRD 6.5.10. The diagnostic data sampling rate, items, formats, and protocols shall be documented in the HSICD.

3.9.3.6.4 Instrument to Spacecraft Transmission Timeouts

The Instrument shall implement an automatic timeout in waiting for the end of data transfer cycle signal from the Spacecraft. If the end of data transfer cycle is not completed by the Spacecraft within the allotted time period, the Instrument shall proceed as if the signal was received in order to prevent disruption of data transfer and instrument operations.

3.10 Software Specifications

3.10.1 Software Language Requirements

All deliverable software shall be implemented using the following standard programming languages; C per ANSI STD X3.159-1989 or FORTRAN per ANSI STD X3.9-1978.

3.10.2 Flight Software Requirements

All flight software and firmware shall meet the requirements in GIRD Section 8.3. and shall be developed in accordance with the requirements of MAR Section 10.

3.10.2.1 Software Development Requirements

Flight software development methodology shall conform to the requirements in MAR Section 10 and in the HIRDLS Flight Software Management Plan, SW-HIR-96.

3.10.2.2 [Deleted]

3.10.2.3 [Deleted]

3.10.2.4 Flight Software Version Control

All flight software and firmware shall be implemented with an internal identifier embedded in the executable program that can be included in the Instrument engineering data.

3.10.2.5 Flight Software On-Orbit Installation and Verification

Any required flight software shall be designed so that revisions can be installed and verified on-orbit.

3.10.2.6 Processor System Resource Utilization

All processor systems, including dedicated embedded programmable controllers used within the Instrument shall individually meet the hardware resource maximum utilization requirements at the identified program phases as shown in Table 3.10.2.6-1.

Phase Resource	PDR	CDR	Acceptance Review
Memory	30%	40%	50%
Processing Bandwidth	30%	40%	50%
I/O Bandwidth	30%	40%	50%

Table 3.10.2.6-1 Processor Resource Utilization Requirements

3.10.3 Flight Software Development Environment

Any software environment tools used during the course of developing the Instrument flight software shall operate under a UNIX operating system that adheres to IEEE 1003.1-1988, Portable Operating System Interface for Computer Environments (POSIX).

The Instrument Integrator shall provide the documentation necessary to operate the development environment and the software development tools.

3.11 Environments

The orbit for the Instrument will be a sun-synchronous near-circular polar orbit with a seasonal-mean ascending node crossing time of 1345 hr ± 15 min. The range of the sun ß angle will be 16 to 36 degrees. The Instrument shall be designed to operate with an orbital altitude of 705 km, allowing for the following variations and uncertainties:

a. ±15 km for uncertainty in mean S/C altitude

b. ±15 km for orbit eccentricity

c. +8, –13 km for earth oblateness

Note: The derivations of orbit-dependent subsystem requirements, e.g. scan range, have assumed the worst-case combination of the above variations.

The Instrument shall be designed to meet all performance requirements after exposure to the ground test, storage, handling, and launch environmental conditions, and during exposure to the operating environmental conditions, specified below.

3.11.1 Random Vibration

The Instrument shall meet all performance requirements after exposure to random vibration testing. The random vibration test levels are specified in GIRD Section 10.1, Tables 10-1 and 10-2.

3.11.2 Sine Vibration

The Instrument shall meet all performance requirements after exposure to sine vibration testing. The test levels are specified in GIRD Section 10.2.

During testing, spectral notching may be permitted in order to meet the requirements of GIRD Section 3.6.3.3.

3.11.3 Acceleration

The Instrument shall withstand the acceleration requirements of GIRD Section 10.3.

3.11.4 Shock

The Instrument shall meet all performance requirements after exposure to the shock environment specified in GIRD Section 10.4.

3.11.5 Acoustic

The Instrument shall meet all performance requirements after exposure to the acoustic environment specified in GIRD Sections 10.6 and 10.7.

3.11.6 Thermal Environments

The Instrument shall be designed to operate within all performance specifications during exposure to the radiative thermal fluxes specified in GIRD Section 4.3.4 and to the S/C temperature ranges specified in GIRD Section 4.4.1.

3.11.7 On-Orbit Vibration Environment

For design purposes, it shall be assumed that the Instrument in orbit will experience simultaneous translational and rotational vibration inputs up to the PSD limits defined in Table 3.11.7-1. The translational inputs shall be assumed to be applied uniformly to the mounting feet of the Instrument at the kinematic mount interface plane and in any direction. Rotational inputs shall be assumed to be applied about any axis through the center of mass of the Instrument.

Frequency Hz	Translational PSD g^2/Hz	Rotational PSD $(rad/s^2)^2$/Hz
0.1	9.3E-15	9.3E-13
0.1-30	+12 dB/octave	+12 dB/octave
30-400	7.0E-5	7.0E-3
400-2000	-12 dB/octave	-12 dB/octave
2000	1.1E-7	1.1E-5

Table 3.11.7-1 Random Vibration Levels

3.11.8 Humidity

The Instrument shall be designed to allow the exercising of all system and subsystem functions in a nominal 1-atmosphere environment where relative humidity is as high as 65% without permanent degradation.

3.11.9 Pressure

The Instrument shall withstand the maximum atmospheric pressure decay rate specified in GIRD Section 10.5.

3.11.10 Radiation

3.11.10.1 Total Ionizing Dose Radiation Environment

The Instrument shall meet all performance requirements in the total ionizing dose environment specified in GIRD Section 10.8.

3.11.10.2 Cosmic Ray and High Energy Proton Environment

The Instrument shall meet all performance requirements in the Cosmic Ray and High Energy Proton Radiation environments specified in GIRD Sections 10.9.1.1 and 10.9.1.2. Predictions of single events (i.e. single event latch-up, single event upset and single event burn-out) induced by galactic cosmic ray ions and high energy protons shall be performed separately and the results combined.

3.11.10.3 Spacecraft Charging

There shall be no electrically floating conductors anywhere in the instrument, except within a conducting enclosure. All unused wires in cable bundles shall be connected to chassis ground.

All circuit boards shall be fabricated in such a way as to be free of loose metalization and/or ungrounded pins or connectors.

A means shall be provided to ground the reflective metalizations on all mirrors that have non-conducting substrates.

3.11.11 Atomic Oxygen

The Instrument shall meet all performance requirements during exposure to the atomic oxygen environment specified in GIRD Section 10.10.

3.11.12 Storage, Handling, and Transportation

During storage and transportation, the Instrument shall be in its shipping container at all times.

When in the shipping container, the Instrument shall have no exposed ungrounded electrical contacts.

During handling and testing (except for testing in vacuum) outside the shipping container, the following relative humidity requirements shall apply:

a. 10% to 65% if no ungrounded electrical contacts are exposed
b. 35% to 65% if ungrounded electrical contacts are exposed

3.12 Contamination Control Requirements

The design, implementation, and handling of the Instrument shall meet all applicable contamination control requirements of GIRD Section 7 as interpreted and extended by PA-HIR-006, HIRDLS Instrument Contamination Control Plan.

Contaminants are defined as either molecular or particulate surface deposits, other than water ice on cryo surfaces, which can degrade Instrument performance.

3.12.1 Materials Selection Criteria

3.12.1.1 Acceptance Screening of Nonmetallics

All nonmetallic materials used in the Instrument shall be shown to meet, as a minimum, the requirements of Total Mass Loss (TML) less than 1.0 percent and Collected Volatile Condensable Material (CVCM) less than 0.1 percent when tested in accordance with ASTM E595. Typical materials falling in this category are polymers, paints, adhesives, potting and staking materials, composites, electronic boards and cables, and MLI. Representative sources containing lists of acceptable materials are NASA RP 1124 and MSFC HDBK 527. A complete list of polymeric and organic materials shall be submitted on GSFC forms 18-59A and B, or an equivalent, containing data for TML, CVCM and the curing or processing time and temperature.

3.12.1.2 Outgassing of Materials and Subsystems

In addition to meeting the screening criteria for TML and CVCM, all materials shall have an outgassing rate that complies with MAR Section 9.3; in particular, the outgassing rate of condensables from all materials and subsystems inside the Instruments shall be less than 3×10^{-11} gm cm^{-2} s^{-1} as measured, during acceptance testing, with a 15 MHz Temperature controlled Quartz Crystal Microbalance (TQCM), with the crystal held at a temperature of –20 °C.

3.12.1.3 [Deleted]

3.12.2 Baseline Requirements for HIRDLS Contamination Control

3.12.2.1 Settled Particulates

Particulate levels on sensitive optical surfaces shall not exceed Level 280, as defined in MIL-STD-1246, prior to pre-launch calibration. Since particulates can migrate from adjacent surfaces, these surfaces shall be maintained at the same levels of cleanliness as the optics.

3.12.2.2 Molecular Contaminants

Molecular contaminants or NVR shall be maintained at or below Level A, per MIL-STD-1246.

3.12.3 [Deleted]

3.12.3.1 Instrument Venting

3.12.3.1.1 Closure and Venting for Launch

a. All apertures shall be closed for launch, except for venting arrangements which shall be included to prevent excessive pressure differential between the outside and inside of the outer structure or any enclosure within the Instrument which is not hermetically sealed.

b. Radiometric apertures shall be protected by covers which can be opened and reclosed on command.

c. For vents required only to accommodate the launch pressure profile, the closure requirement may be met by a spring-loaded flap opening outward.

d. Pumping apertures of any size and other non-radiometric apertures of area greater than 5.0 mm^2 shall be covered during launch by fixed mesh filters sized to block the passage of particles larger than 0.5 mm diameter and to obscure the aperture area by no more than 20%.

3.12.3.1.2 Outward Venting

a. Electronics units shall not be vented within or into the OBA interior volume. Exterior vents shall be directed away from the spacecraft and from critical apertures and surfaces of other instruments.

b. Exterior vent locations shall be approved by the Spacecraft Contractor. The number, location, size, vent path and operation time of exterior vents shall be defined and this information provided to the Spacecraft Contractor for documentation in the HSICD.

3.12.3.1.3 Inward Venting

Inward venting will be required following exposure of the Instrument to vacuum during ground testing and calibration, and during storage and shipping to accommodate ambient pressure changes. Provision for such inward venting shall meet the following requirements:

a. During inward venting, no less than 95% of air or gas entering the instrument outer structure shall have passed through a suitable filter which will trap any particle greater than 5 µm in diameter.

b. During inward venting, no less than 99% of air or gas entering the Telescope Subsystem and its associated optical paths shall have passed through a suitable filter which will trap any particle greater than 5 µm in diameter.

3.12.4 Sources of Contamination

3.12.4.1 [Deleted]

3.12.4.2 [Deleted]

3.12.4.3 Impact of HIRDLS Emissions on Other Instruments

External emissions from the Instrument shall be in compliance with the GIRD, Sections 7.2 and 7.3.

3.12.5 Verification of Cleanliness Levels

During assembly, integration, test, and calibration of the Instrument, periodic tests to verify maintenance of the required cleanliness levels shall be performed in compliance with the HIRDLS Contamination Control Plan, PA-HIR-6.

3.12.6 Protective Measures to Maintain Cleanliness

To help preserve the cleanliness of the hardware at the piece part level, the subassembly level and at the system level, protective measures shall be used as required by the HIRDLS Contamination Control Plan, PA-HIR-6.

Prior to launch the Main Aperture door (moveable sunshield) and Space View Aperture door shall remain closed except:

a. when tests are to be conducted on the above mechanisms;

b. when the Instrument is required to view external targets.

3.12.6.1 [Deleted]

3.12.7 [Deleted]

3.13 Reliability and Safety Specifications

The Instrument and its subsystems designs shall meet all requirements for quality, reliability, safety, and maintainability specified in MAR Section 7 and herein.

3.13.1 Instrument Reliability Level

The Instrument shall be designed to meet the "Instrument" reliability level specified in Table 5.1–3, i.e. it shall be shown by analysis that the probability of the Instrument operating within specifications over the operational lifetime defined in Section 3.13.2 is at least the "Instrument" value shown in Table 5.1-3. The initial allocation of Reliability Levels among subsystems is specified in Table 5.1-3.

3.13.2 Operational Life

The Instrument shall be designed for 8 years of operating life (3 years S/C integration, test, and calibration, plus 5 years in orbit).

3.13.3 Storage Life

The Instrument shall be designed to meet the other requirements of this specification after a storage period, either in an instrument storage container or on the EOS spacecraft, for up to one year in the environment specified in Section 3.11.12.

Age-sensitive parts, materials, and components shall be identified in accordance with MAR Section 6.2.5.3. Storage containers shall meet requirements of Section 3.18.

3.13.4 Data Reliability

Pursuant to the objective of continuous acquisition of valid data during the lifetime of the Instrument in orbit, the following requirements shall be considered design guidelines for the purposes of component selection and design of the overall system architecture. Compliance with the requirements in this section need not be verified by test or formal analysis.

The design of the Instrument shall include such features as are required to limit data outages according to the criteria listed below. For the purposes of this requirement, an “outage” shall be defined as any period of non-transmission of valid science or engineering data, whether or not so identified in telemetry, when the Instrument is powered and in a mode in which science and/or engineering data would normally be transmitted.

a. Unscheduled data outages due to any Instrument malfunction, and requiring ground intervention for the resumption of normal operation, shall not exceed one event in any 6-month period.

b. Unscheduled data outages due to any Instrument malfunction that can be corrected autonomously so that normal data acquisition resumes within 10 minutes or less shall not exceed one event in any 10-day period.

c. Periods of data corruption (e.g. due to SEUs) affecting no more than two contiguous vertical scans shall be limited to one event per orbit.

3.14 Quality Assurance Requirements

All design, procurement, and fabrication activities associated with the production of the Instrument shall be conducted under a quality assurance program complying with MAR Section 8.

3.14.1 Identification and Marking

The Instrument and its components shall be permanently marked in a conspicuous area with the part number, serial number, configuration identifier and the drawing number, as a minimum. Materials used for marking and identification shall comply with the contamination control requirements of this specification.

3.14.2 Configuration Control

The Instrument as-built configuration shall be controlled and verified in accordance with the HIRDLS Configuration Management Plan and MAR Section 5.3.

3.14.3 [Deleted]

3.14.4 Fabrication Control

3.14.4.1 Electrostatic Discharge Control

The Instrument is sensitive to electrostatic discharge (ESD). All electrical and electronic parts, assemblies, and equipment susceptible to damage caused by static electricity shall be handled in accordance with the HIRDLS PAIP.

3.15 Instrument Operational Concepts

3.15.1 Instrument Commanding Philosophy

The Instrument is a scientific research instrument which will be used to collect data over at least a five year operational life-time. Due to the length of the mission and to the difficulty of predicting all possible operational scenarios which may be required during the life of the Instrument, a flexible commanding structure shall be implemented. This structure shall allow the Instrument to operate without requiring ground intervention more often than once per day.

3.15.2 Instrument Monitoring and Safing Philosophy

In order to maintain the safety and operational status of the Instrument and its various critical components, engineering data indicating the status of each of the critical instrument components shall be collected and monitored on a routine basis. Critical parameters shall be checked against stored limit values at a frequency sufficient to allow effective action to prevent component damage. If a component is in danger of being damaged, the Instrument shall provide the ability to safe itself in a manner which will protect the critical component. Minor anomalies which occur during normal instrument operations and which do not present a risk of component damage or degradation shall not cause the Instrument to enter a safe state.

3.16 Safety Requirements

The Instrument and associated ground support equipment shall comply with the safety requirements of MAR Section 11.

3.16.1 [Deleted]

3.17 Design and Construction Requirements

The Instrument shall use qualified parts and materials with the emphasis on standardization, so as to limit the number of different types used.

3.17.1 Use of Metric Components

All mechanical components used in the Instrument, including threaded fasteners, shall conform to standard ISO metric sizes and specifications. In the event of the unavailability of appropriate metric hardware, exceptions to this requirement will be considered on a case-by-case basis.

3.17.2 Parts

Parts used on HIRDLS flight hardware shall meet the requirements for a Grade 2 parts quality level as described in MAR Section 5.

3.17.3 Materials and Processes

Selection of materials and processes for use on HIRDLS flight hardware shall comply with the requirements of MAR Section 6.

3.18 Performance Verification Requirements

Performance verification shall be conducted in accordance with the HIRDLS Performance Verification Plan, TP-HIR-8, and MAR Section 3.

3.19 Documentation Requirements

3.19.1 Use of Système International (SI) Units

All deliverable documentation pertaining to the Instrument, including, but not limited to, drawings, analysis and tradeoff reports, handbooks, procedures, test plans, test results, operating manuals, and math model outputs, shall present all technical data, parameters, dimensions, and equations in SI units per ISO 1000.

3.19.2 Instrument Interface Control Drawing Requirements

An Instrument Interface Control Drawing (ICD) will be generated by the Spacecraft Contractor with input from the Instrument Integrator. Input for the HSICD shall be provided to the Spacecraft Contractor in accordance with the GIRD. All interfaces shall be specified in SI units.

3.19.3 Internal Interface Control Document Requirements

All interfaces between subsystems shall be documented in the HIRDLS Interface Control Documents, SP-HIR-2XX. Interface definitions shall be included for all mechanical, optical, electrical and thermal interfaces. Each interface definition shall include the interface requirements for both sides of the interface. All internal interface dimensions and parameters shall be specified in SI units.

3.19.4 Data Interface Documentation Requirements

All data interfaces, both between subsystems and between the Instrument and the Spacecraft, shall be documented in the HIRDLS Command & Telemetry Handbook (C&TH), SP-HIR-103. This documentation shall include data formats, data rates, packet definitions, command protocols, command and telemetry mnemonics, command criticality, and any other information necessary to ensure data compatibility within the Instrument, between the Instrument and the Spacecraft, and between the Instrument and the HIRDLS Ground Data System.

4 SUBSYSTEM REQUIREMENTS

4.1 Structure/Thermal Subsystem

4.1.1 Subsystem Description

The Structure/Thermal Subsystem (STH) provides the primary Instrument structural support and structural link to the S/C, maintaining optical alignment for all specified environmental conditions. The STH provides a stable, environmentally controlled enclosure for the Instrument. The Radiator Panels, Outer Structure with closure panels, and Multi-Layer Insulation (MLI) are part of the STH. The Radiator Panels in turn support the Cooler, Instrument Processor, and Power Subsystems.

The Interface Alignment Cube (IAC) is mounted on the STH for the alignment of internal components to the Instrument and, of the Instrument to the S/C.

The STH manages the thermal environment within the Instrument during flight and ground testing by conducting and radiating heat from internal subsystems to the Radiator Panels mounted on the +Y (anti-sun) side of the Instrument. The Radiator Panels are of sufficient area to provide passive cooling to space, maintaining proper Instrument operating temperatures for all operating modes, and all flight environmental conditions. During ground testing, the Radiator Panels conduct or radiate heat to GSE cooling plates to simulate the flight environment. Survival Heaters powered directly from the S/C Survival Heater Bus actively maintain safe startup temperatures for Instrument systems during periods of Instrument shutdown. MLI on all exterior surfaces (except Radiator Panels) blocks radiative heat load from the S/C, earth, and sun. Surface finishes are used to control radiative heat transfer. The Instrument is thermally de-coupled from the S/C by mounts provided by the S/C.

The STH accommodates electrical connectors, electrical harnesses, and is the primary ground plane for the Instrument.

4.1.2 Modes of Operation

STH modes of operation shall be defined so as to support the Instrument modes of operation defined in Section 3.2.

4.1.3 Mechanical Requirements

4.1.3.1 Structure/Thermal Subsystem Envelope

The STH shall be contained within the envelope specified in UIID Figure 3-2. The STH structure shall have sufficient stiffness to support all Instrument subsystems, while confining displacements within the envelope, for all specified environments.

4.1.3.2 Mass

The mass of the STH shall not exceed the value specified in Table 5.1-1.

4.1.3.3 Lifting Points

The STH shall incorporate external lifting points that allow handling during testing, mounting of the Instrument to the S/C, and to the required test and calibration facilities.

Location of lifting points shall be such that the requirements of Section 3.6.3.1 can be met.

4.1.3.4 De-Pressurization and Venting

The STH shall withstand the maximum pressure decay rate specified in GIRD Section 10.5, with the Sunshield Door closed. If necessary, a spring-return venting flap may be used.

The Outer Structure shall provide individual venting paths for internally mounted units that require venting per the criteria of Section 3.12.3.1.

4.1.3.5 Access

Access shall be provided for manual operation of caging mechanisms. All access provisions shall comply with the HSICD. The Outer Structure shall be designed to provide the required access for calibration without interfering with the proper thermal control of the Instrument.

4.1.3.6 Mechanical Performance

The STH shall meet the requirements of Section 3.6.4 by having sufficient structural stiffness so that the Instrument, configured for launch, has a minimum fixed-base frequency of 50 Hz. For the purpose of this requirement, "fixed-base" is defined as a condition in which each mounting point is constrained in those degrees of freedom which are constrained when the instrument is attached to the Spacecraft, and each mounting point is free in those degrees of freedom for which the Spacecraft attachment mounts provide flexibility.

4.1.3.7 Mechanical Interfaces

Each mounting interfaces between the STH and a subsystem/unit shall comply with the relevant interface control document listed in Table 4.1.3.7-1.

STH Interface to–	Interface Control Document
Sunshield Subsystem (SSH)	SP-HIR-212
Gyro Electronics Unit (GEU)	SP-HIR-213
Telescope Subsystem (TSS)	SP-HIR-214
In-Flight Calibrator Subsystem (IFC)	SP-HIR-216
Instrument Processor Subsystem (IPS)	SP-HIR-217
Cooler Subsystem (CSS)	SP-HIR-218
Power Subsystem (PSS)	SP-HIR-219
Spacecraft (S/C)	TRW-D26477, HSICD

Table 4.1.3.7-1 STH ICD Summary

The STH shall meet the mechanical requirements of Sections 3.6.3.1 through 3.6.3.2.3.

4.1.4 Electrical Requirements

4.1.4.1 Input Power Requirements

4.1.4.1.1 Power Allocation

The total power consumption of the STH from the Survival Heater buses SHA and SHB shall comply with the requirements of Section 3.7.8.

4.1.4.1.2 Primary Power

The STH shall derive power from Survival Heater Power Buses, SHA and SHB, to power Survival Heaters as described in Section 3.7.8. The Survival Heaters shall be redundant, electrically isolated from each other and from the chassis, and shall have independent power returns. Isolation between the Survival Heater Power Buses shall be greater than 1 MΩ.

4.1.4.1.3 Secondary Power

There shall be no secondary power required for the STH.

4.1.4.2 Grounding Requirements

The STH structure shall be the Signal Reference Plane for the Instrument. The STH shall include an external chassis ground tie point to the signal reference plane, as required by GIRD Section 5.3. All Instrument component chassis shall be electrically connected to the signal reference plane.

4.1.4.2.1 Primary Power Grounding

The Survival Heater Power Buses shall have independent return lines. Isolation between survival power or return lines and the STH shall be greater than 1.0 MΩ.

4.1.4.2.2 Secondary Power Grounding

There shall be no secondary power grounding required for the STH.

4.1.4.3 Electrical Interfaces

The electrical interface between the STH and the S/C shall meet the requirements of Section 3.7.1.

All electrical interfaces between the STH and subsystems/equipment mounted to it shall comply with the applicable interface control documents (see Table 4.1.3.7-1).

4.1.5 Thermal Requirements

4.1.5.1 Survival Heaters

The thermal characteristics of the Survival Heaters shall comply with the requirements in Section 3.7.8.

4.1.5.2 Thermal Blankets

Multi-Layer Insulation (MLI) thermal blankets shall be used to limit radiative transfer of heat between the Instrument and the external environment. All MLI blankets shall be removable up to 10 times without damage or thermal degradation. Provision shall be made in the MLI for venting during launch. The MLI shall be protected from damage during shipping and handling.

The configuration of thermal blankets shall conform to the applicable requirements in SP-HIR-111, Thermal Interface Requirements Document.

Thermal blankets shall be grounded in compliance with GIRD Section 5.3.5.2.

Thermal blankets shall be designed to perform within specifications over the life of the Instrument in orbit when exposed to the orbital environment defined in GIRD Sections 10.8, 10.9, and 10.10.

4.1.5.3 Radiators

There shall be an Electronics Radiator Panel and a Cooler Radiator Panel. Radiator surface finishes shall meet the requirements of Section 3.12. Allocated radiator fields of view are shown in UIID Figure 3-3.

4.1.5.3.1 Temperature Variation at Unit Mounting Faces

The temperature variation of the Cooler and Electronics mounting faces over the period of one orbit shall not exceed 5 K peak-to-peak for analog electronics and 10 K peak-to-peak for digital electronics

4.1.5.3.2 [Deleted]

4.1.5.4 Thermal Interfaces

The STH thermal design shall primarily utilize radiative heat transfer to space for thermal control. Conductive heat transfer through the Instrument mounting feet shall not be used as a heat flow path. The thermal interface between the Instrument Baseplate and the S/C shall meet the requirements of Section 3.8.1. For modeling purposes, the maximum thermal conductance of each of the kinematic mounts supplied by the Spacecraft Contractor shall be assumed to be 80 mW/K per HSICD Section 4.3.1.1.

The STH thermal interfaces are:

a. Radiative to space
b. Radiative to all internal subsystems
c. Conductive to Sunshield Subsystem
d. Conductive to Cooler and Electronics Radiator Panels
e. Conductive to Optical Bench and Gyro Electronics Unit

Specific thermal interfaces between the STH and subsystems/equipment mounted to it shall conform to the requirements of SP-HIR-111, Thermal Interface Requirements Document.

4.1.6 Environments

The STH shall ensure that the overall Instrument performance requirements are met after exposure to the environments specified in Section 3.11.

4.1.7 Reliability Requirements

The STH reliability shall meet the requirements of Table 5.1-3.

4.2 Sunshield Subsystem

4.2.1 Subsystem Description

The Sunshield Subsystem (SSH) prevents direct sunlight from entering the Instrument optics and reduces solar and earth albedo heat gains into the viewing aperture. It consists of a fixed external sunshield, moveable Sunshield Door with frame-mounted Drive Mechanism, Hold-down/Release Mechanism, and Sun Sensors. The SSH mounts to the +Z face of the Instrument Outer Structure.

A fixed external sunshield reduces earthshine and albedo flux entering the Instrument aperture while allowing full travel of the Sunshield Door. The frame provides structural support for the SSH elements and a mechanical load path to the Instrument Outer Structure. The aperture plate encompasses the composite field of view. The Sunshield Door is moved by the Drive Mechanism which includes a drive motor, door position sensor, and sensors to indicate the door fully open and fully closed positions. Fixed baffles, located just inside the aperture, contribute to stray light control within the Instrument.

The Hold-down and Release Mechanism (HRM) functions, without the use of electrical power, to constrain the door during launch, allowing the structural dynamics requirements to be met. Sensors indicate the latched or unlatched status of the HRM.

The IPS uses signals from the Sun Sensors, door position information from the Drive Mechanism-Angle Sensor, equator crossing time markers from the Spacecraft OBC, and internal lookup tables to control the Sunshield Door during the mission mode. The Instrument will be capable of taking Science data while the door is in motion.

Included with this subsystem is a Space View Aperture (SVA) door which closes the chopper reference space view aperture in the +Y face of the Instrument, to prevent the ingress of contaminating particles during launch. It consists of a plane shutter which can be rotated approximately in its own plane through a 90° angle by means of a dc-motor/gearbox actuator. There is no separate hold-down/release mechanism for the SVA door.

4.2.2 Modes of Operation

SSH modes of operation shall be defined so as to support the Instrument modes of operation defined in Section 3.2.

4.2.2.1 Ground Operations

The Sunshield Door shall be closed and latched during ground handling and storage, and when aperture viewing is not required during testing, except when the Instrument is in vacuum. When closed, the door is not required to provide a gas tight seal, but shall effectively prevent entry of particulate contamination. The SSH shall be capable of opening, and closing the Sunshield Door fully in a 1g environment, on command from the IPS, using power from the S/C and without GSE, with the Instrument Z-axis within 30° of vertical.

The SVA door shall be closed during ground handling and storage, and when space viewing is not required during testing, except when the Instrument is in vacuum. When closed, the door is not required to provide a gas tight seal, but shall effectively prevent entry of particulate contamination. The SVA door shall be capable of opening and closing fully in a 1g environment, on command from the IPS, using power from the S/C and without GSE, with the Instrument Z-axis within 30° of vertical.

4.2.3 Functional Requirements

4.2.3.1 Closure and Shielding

An aperture plate shall be provided for the main viewing aperture, having a cut-out forming the instrument aperture. This aperture shall conform to the shape defined in SP-HIR-224, SSH to TSS ICD. The Sunshield Door shall be opaque and shall fully cover the main viewing aperture when closed. The movable door and the fixed components of the Sunshield Subsystem shall be designed so as to exclude direct sunlight from the interior of the Instrument at all times during normal operation.

4.2.3.2 Drive Mechanisms

The Sunshield Door Drive Mechanism shall be capable of moving the Sunshield Door through the full range of motion allowed by the design of the fixed sunshield. The time required to move the door to the Safe position from any other position shall not exceed 30 s. For this purpose the Safe position shall be taken as open 60°. All other commanded door motions shall be completed in a time not to exceed T given by:

$$T = \frac{A}{2} + 1$$

where T is in seconds and A is the required change of door angle in degrees. The SSH shall be designed to produce the required motion without violating the torque constraints of GIRD Section 3.10 and any additional constraints imposed by other Instrument subsystems, e.g. the TSS.

The Sunshield Door drive mechanism motor shall have a minimum torque margin of three.

The Sunshield Door drive system shall be capable of changing the sunshield door angle in steps of 0.25° or less.

The SVA drive mechanism is required to move the door only between the fully open and fully closed positions, which shall be defined by mechanical stops. The SVA drive motor shall have a minimum torque margin of three.

4.2.3.3 Angle Sensors

The Drive Mechanism Angle Sensor shall monitor continuously the Sunshield Door angle relative to the fully closed position with a resolution of 0.25° or less, and with an absolute accuracy over the operational life of the Instrument of ±2.0°.

The SVA door mechanism shall include position/limit switches for monitoring the fully open and fully closed positions.

4.2.3.4 Hold-down and Release Mechanism

The Hold-down and Release Mechanism (HRM) shall hold the Sunshield Door in a latched condition during launch, and release the Sunshield Door on command from the IPS when in orbit. The HRM shall be capable of completing the release cycle within 5 minutes after receiving the command from the IPS. The release mechanism shall be of the electro-mechanical, or hot wax actuator type. Pyrotechnic devices shall not be used.

Actuators for the release function shall be redundant. There shall be no single-point failure mode that would prevent unlatching of the Sunshield Door in orbit by ground command.

4.2.3.4.1 Latching Without Power

The HRM shall be easily accessible for manual latching, shall be manually latchable without the use of any tool and shall not require electrical power to remain latched or unlatched.

4.2.3.4.2 Latching Status

The HRM shall generate a status signal for the position of each latch point. The position status of the HRM shall be indicated by redundant bi-level sensors.

4.2.3.5 Sun Sensors

Sun Sensors, independent of the Sunshield Door drive mechanism angle sensor, shall be used in combinations as required to determine:

a. whether the Instrument is in "day" or "night"

b. when the sun is illuminating the –X face of the Instrument such that it could potentially shine into the main viewing aperture

c. the position of the edge of the shadow cast by the Sunshield Door, at at least one door angle, in order to verify door operation

Each sensor shall be monitored by telemetry at a rate of at least one sample per second.

4.2.3.6 Fixed Baffles

Fixed external and internal baffles shall be designed, as part of the overall Instrument stray light plan, to limit earth and albedo flux within the main viewing aperture.

4.2.4 Mechanical Requirements

All elements of the sunshield subsystem, including lubrication techniques used for the Sunshield mechanisms, shall comply with the contamination control requirements of Section 3.12.

4.2.4.1 Envelope

The SSH shall be contained within the envelope specified in the UIID and in SP-HIR-212, STH to SSH ICD.

4.2.4.2 Mass

The SSH mass shall not exceed the value specified in Table 5.1-1.

4.2.4.3 Mechanical Performance

The SSH shall comply with the stiffness requirements for the launch configuration specified in Section 3.6.4. For the purpose of meeting this requirement, the Sunshield Door shall be constrained during launch by the mechanism described in Section 4.2.3.4.

4.2.4.3.1 [Deleted]

4.2.4.3.2 Door Motion Disturbances

Dynamic reaction disturbances due to movements of the Sunshield Door shall not exceed the instrument-level values specified in GIRD Section 3.10.

4.2.4.4 Mechanical Interfaces

The SSH shall have mechanical interfaces to the STH conforming to the requirements of SP-HIR-212, STH to SSH ICD.

4.2.5 Electrical Requirements

The electrical properties of all SSH components that interface to the IPS shall comply with the interface requirements documented in SP-HIR-227, SSH to IPS ICD.

4.2.5.1 Input Power Requirements

4.2.5.1.1 Primary Power

There shall be no primary power required for the SSH.

4.2.5.1.2 Secondary Power

All secondary power to the SSH shall be provided by the Sunshield Control Electronics located in the IPS. The power consumption of the SSH shall not exceed the value specified in Table 5.1-2. The electrical interface between the SSH and the IPS shall be as defined in SP-HIR-227, SSH to IPS ICD.

4.2.5.2 Grounding Requirements

4.2.5.2.1 Primary Power Grounding

There shall be no connection to the primary power ground on the SSH.

4.2.5.2.2 Secondary Power Grounding

There shall be no connections made between the secondary power ground and either chassis ground or primary power grounds. The secondary grounds in the SSH shall be isolated by at least 1.0 MΩ from chassis or primary power grounds.

4.2.5.3 Electrical Interfaces

The SSH assembly electrical interface with the IPS shall conform to SP-HIR-227, SSH to IPS ICD.

4.2.5.4 Electromagnetic Disturbances

Operation of the Sunshield Door Drive Mechanism shall not create electromagnetic disturbances that prevent the Instrument from acquiring uncorrupted Science Data continuously during changes of door position.

4.2.6 Thermal Interfaces

The SSH thermal interfaces shall be:

a. Radiative interface with the internal Instrument environment

b. Radiative interface with the external environment

c. Conductive interface with the STH Outer Structure

Specific thermal interface characteristics, including surface finishes, shall comply with SP-HIR-111, Thermal Interface Requirements Document.

4.2.7 Environments

The SSH shall be designed such that the Instrument meets the overall performance requirements after exposure to the environments specified in Section 3.11.

4.2.8 Reliability Requirements

The SSH shall be designed to have a reliability factor as specified in Table 5.1-3.

4.3 Gyro Subsystem

4.3.1 Subsystem Description

The Gyro Subsystem (GSS) is a reliable, high precision, low-noise strapdown inertial reference unit consisting of two assemblies: a rate gyro assembly referred to as the Gyro Mechanical Unit (GMU), and an associated electronics assembly referred to as the Gyro Electronics Unit (GEU). The GMU is rigidly mounted to the Optical Bench (OB), and the GEU is mounted on the Instrument Baseplate. The GMU contains rate gyros each of which measures rotation rate about its input axis relative to inertial space. These input axes are aligned so as to permit determination of the rotation of the GMU about three orthogonal axes from the gyro output data. The GMU alignment relative to the TRCF is determined by pre-launch measurements. The GMU includes an internal temperature control system which dissipates heat conductively to the OB across the mounting interface, and a set of flux-gate magnetometers to facilitate correction of the gyro data for variations in the ambient magnetic field.

The GEU contains all of the circuitry necessary to operate and control the GMU, including power filtering, temperature controllers, digital electronics, and electrical interfaces. The GEU filters and integrates the rate signals from the GMU, and outputs digital attitude data to the IPS.

GSS electrical interfaces include power input from the PSS; a bi-directional asynchronous serial link to the IPU for commands, status, and engineering data; a data strobe input from the IPU; and a high-speed unidirectional serial output from the GSS to the IPS for angle and magnetometer data.

4.3.2 Modes of Operation

GSS modes of operation shall be defined so as to support the Instrument modes of operation defined in Section 3.2.

4.3.3 Performance Requirements

The component of rotation of the GMU about each of three orthogonal axes shall be given by linear combinations of the integrated rate digital counts from each gyro channel. For the purposes of the following specifications, the three specified axes are those of a coordinate frame nominally aligned with the SRCF, but fixed relative to the GMU mounting feet.

The performance requirements about each of these three axes are expressed in terms of an equivalent angle about that axis. The term "equivalent angle" means the angular rotation about the axis inferred from the linear combination of the gyro channel outputs, including corrections for offset, scale factor, and other GSS parameters characterized before launch. Additional ground data processing will be required for meeting the GSS performance requirements for periods longer than about 10 s.

4.3.3.1 Digital Rate Output

The GSS shall telemeter to the IPS, for each gyro channel, a digital count representing the integrated rate about that channel's input axis. Transmission of each data set shall be initiated by receipt at the GEU of a Data Transmit command. The integrated rate count shall be latched within the GEU within 20 μs after the trailing edge (low-to-high transition) of the GSS Synch pulse. The rate integration counter width and the word length transmitted to the IPS shall be sufficient to ensure unambiguous angle data for GSS Synch repetition rates ≥ 75 Hz.

For constant input rates, the integrated rate digital count for each gyro channel shall be related to the actual change in angle about that channel's input axis, relative to inertial space, by the following equation:

$$[\Delta\text{Count}] = [\text{ScaleFactor}]*([\text{InputRate}]+[\text{DriftRate}])*[\text{IntegrationTime}]$$

where [ΔCount] is the change in the rate integration counter value since the previous GSS Synch pulse (accounting for rollover), [ScaleFactor] and [DriftRate] are constant to within the specified noise and drift limits, and [IntegrationTime] is the time between successive GSS Synch pulses.

4.3.3.2 Angular Measurement Requirements

The following requirements on equivalent angle knowledge, relative to the TRCF, shall be met in the on-orbit thermal and vibrational environment specified in Section 3.11, and with additional constant rotational inputs in the range 0 ±20, 220 ±20, and 0 ±20 arcsec/s about the TRCF X, Y, and Z axes respectively. In addition, the gyro shall operate with no degradation to the equivalent angle measurements when subject to constant rates of up to 500 arcsec/s about any axis.

Note: In order to meet the instrument-level LOS knowledge requirements, the use of data from the Instrument Science Data telemetry stream, in particular, radiance and scanner axis data, is required. The following performance requirements apply specifically to the GSS output data.

4.3.3.2.1 Elevation Requirements

For measurements made with a bandwidth equal to the pointing bandwidth, the random error component of the equivalent angle about the elevation axis (defined as a line perpendicular to the plane defined by the ILOS and the TRCF Z axis; see Figure 3.5-1) between any two single samples, separated by up to 10 s, shall be not more than 1.0 arcsec, 3 σ; this shall include the error (if any) induced by the presence of random ILOS jitter as specified in Section 4.4.10.2.3.

For measurements made with a bandwidth equal to the pointing bandwidth, the systematic error component of the equivalent angle about the elevation axis between any two single samples, separated by up to 10 s, shall be not more than the greater of 0.09% of the angle or 0.12 arcsec.

The uncertainty in mean equivalent angle about the elevation axis, between two sets of measurements, made with a bandwidth equal to the pointing bandwidth and each covering a separate 10 s period, shall be no more than 2.0 arcsec when the sets of measurements are separated in time by any interval in the range of 10 s to 66 s, and by no more than 2.0 arcsec when the sets of measurements are separated in time by any interval in the range of p-132 s to p+132 s, where p is the orbital period.

4.3.3.2.2 Azimuth Requirements

The uncertainty in mean equivalent angle about the azimuth axis (the TRCF Z axis), between two sets of measurements, made with a bandwidth equal to the pointing bandwidth and each covering a separate 10 s period, shall be no more than 62 arcsec when the sets of measurements are separated in time by any interval in the range of 10 s to 66 s, and no more than 62 arcsec when the sets of measurements are separated in time by any interval in the range of p-132 s to p+132 s, where p is the orbital period.

4.3.3.3 Survival Rates

The GSS, when powered or unpowered, shall survive and meet all of the requirements specified in this document after exposure to angular rates up to, and including, 360 °/s about any axis.

4.3.3.4 Warm-up Time

Each channel of the GSS shall reach thermal equilibrium and full operational capability within 4 hr after turn on during operation in air at standard temperature and pressure (STP), and within 8 hr after turn on during operation in vacuum. This requirement need be met only when electrical and thermal interface conditions are within their operational ranges as specified herein.

4.3.4 Mechanical Requirements

4.3.4.1 Gyro Subsystem Envelope

The Gyro Subsystem shall be contained within the envelopes specified in SP-HIR-213, STH to GSS ICD, and SP-HIR-234, GSS to TSS ICD.

4.3.4.2 Mass Allocation

The mass of the GSS, including interconnecting cables between the GEU and GMU, shall not exceed the value specified in Table 5.1-1.

4.3.4.3 GMU-GEU Interconnection

The electrical design of the GSS shall allow the GMU-GEU interconnection cable to be up to 2 m long.

4.3.4.4 Alignment

The GMU shall include such external alignment features as are required to ensure that the angular measurement requirements of Section 4.3.3.2 can be met. Details of these features shall conform to SP-HIR-234, GSS to TSS ICD.

4.3.4.4.1 [Deleted]

4.3.4.5 Mechanical Interfaces

The Gyro Subsystem mechanical interface with the STH shall be as defined in SP-HIR-213, STH to GSS ICD, and the Gyro Subsystem mechanical interface with the TSS shall be as defined in SP-HIR-234, GSS to TSS ICD.

4.3.4.6 Pressurization and Venting

Sealed, pressurized volumes in the GMU shall meet the requirements of GIRD Section 3.6.5. Unsealed GSS volumes shall be vented to the exterior of the instrument.

4.3.5 Electrical Requirements

4.3.5.1 Input Power Requirements

The power consumption of the GSS shall not exceed the value given in Table 5.1-2. Supply voltages as defined below are available to the GSS. The GSS shall be designed to withstand, in any mode, the removal of power from any combination of power input lines without sustaining damage or permanent calibration shifts. Following any such power anomaly, and after restoration of normal power at all input voltages, the GSS shall be capable of executing a normal power-up sequence and shall perform within specifications after the normal warm-up period.

4.3.5.1.1 Primary Power

Switched primary power required by the GSS will be furnished by the PSS. Primary power usage by the GSS shall conform to the requirements of SP-HIR-239, GSS to PSS ICD.

4.3.5.1.2 Secondary Power

All secondary power to the GSS will be provided by the PSS. Secondary power usage by the GSS shall conform to the requirements of SP-HIR-239, GSS to PSS ICD.

4.3.5.2 Isolation and Grounding Requirements

Within the GSS, the configuration of power and return lines, including required isolation, shall conform to SP-HIR-239 Section 3.6.

4.3.5.2.1 [Deleted]

4.3.5.2.2 [Deleted]

4.3.5.3 EMI/EMC Requirements

The GSS shall meet the electromagnetic compatibility and magnetic requirements defined in Section 3.7.6.

Susceptibility of the GMU to magnetic fields shall be sufficiently well characterized that the performance requirements specified herein can be met in the presence of an externally-generated magnetic field in any direction and of any magnitude in the range 0-500 µT. Any magnetic field monitoring hardware required for meeting this requirement shall be part of the GSS.

4.3.5.4 Electrical Interfaces

The electrical interface between the Instrument and the GSS shall be exclusively with the GEU. Connector pin assignments and wire harnesses shall follow established design practices with respect to signal isolation, shielding, functional grouping, and adequate spares provision. Pin assignments shall comply with established program design policy. Electrical contact redundancy, protection, and bonding shall conform to the requirements of Section 3.7.

A test connector shall be provided on the GEU so that during pre-launch testing, internal test points can be monitored and external stimuli can be applied to the GSS. Test points for monitoring internal functions during ground testing shall be buffered to prevent damage or degradation in performance due to accidental shorts of any test point to the test connector shell or to any other test point. The test connector shall be provided with a metal cap which can be permanently attached to provide a complete RF seal around the connector.

All interface characteristics, including signal information, connector identification, and pin assignments, shall be as defined in SP-HIR-237, GSS to IPS ICD; and SP-HIR-239, GSS to PSS ICD.

4.3.6 Thermal Requirements

4.3.6.1 [Deleted]

4.3.6.2 Thermal Interfaces

4.3.6.2.1 GMU Thermal Interface

The GMU thermal interfaces are:

a. Radiative interface with the internal HIRDLS environment

b. Conductive interface with the Optical Bench

Specific thermal interface characteristics, including surface finishes, shall be as defined in SP-HIR-111, Thermal Interface Requirements Document.

4.3.6.2.2 GEU Thermal Interface

The GEU thermal interfaces are:

a. Radiative interface with the internal HIRDLS environment

b. Conductive interface with the STH

Specific thermal interface characteristics, including surface finishes, shall be as defined in SP-HIR-111, Thermal Interface Requirements Document.

4.3.7 Control and Data Requirements

The physical communication interface between the GSS and the IPU shall be as defined in SP-HIR-237, GSS to IPS ICD. Control and data communication shall follow the protocol and data formats defined in SP-HIR-103, C&TH.

4.3.8 Environments

The GSS shall meet the performance requirements specified herein after exposure to the environments specified in Section 3.11.

4.3.9 Reliability Requirements

The GSS shall be designed to have a reliability factor as specified in Table 5.1-3.

4.4 Telescope Subsystem

4.4.1 Subsystem Description

The Telescope Subsystem (TSS) consists of an Optical Bench mounted to the Baseplate, on which are mounted optical components, and the scanner and chopper mechanisms. The line of sight of the telescope is primarily determined by the setting of the 2-axis scan mirror. To achieve the required radiometric accuracy, a chopper provides the detectors with alternating views of the atmospheric scene and a stable reference; synchronous demodulation of the detector outputs creates a signal for each of the 21 channels that is approximately proportional to the difference between the scene radiance and the reference radiance. Precision angular transducers attached to the scan mirror, together with the data from the Gyro Subsystem are needed to provide precise knowledge of the ILOS at all times.

4.4.2 Modes of Operation

TSS modes of operation shall be defined so as to support the Instrument modes of operation defined in Section 3.2.

4.4.3 Imaging Requirements

4.4.3.1 System Aperture

4.4.3.1.1 Positions of Stops and Pupils

The system aperture stop (SAS) shall be transmissive and shall be located, along the optical path, on the detector side of the chopper. The positions of all stops and pupils shall be chosen with due consideration given to the accommodation of any baffles and partitions required for stray light suppression.

4.4.3.1.2 System Aperture Size

For each channel, the entrance pupil of the system, for an object at infinity, shall have an area not less than 0.018 m^2 for all field angles within that channel's IFOV.

4.4.3.2 Focal Length

The effective focal length of the Telescope at the detector focus shall be 242 mm ± 4.0 mm.

4.4.3.3 Field of View

The Field of View (FOV) of the TSS shall accommodate the baseline channel layout shown in Figure 4.5.1-1 assuming a viewing distance of 3000 km.

4.4.3.4 [Deleted]

4.4.3.5 Spectral Performance

The spectral performance of the TSS shall be such that the instrument-level spectral requirements given in Sections 3.4.1, 3.4.2, and 3.4.3 can be met.

4.4.3.6 Optical Surface Durability

All optical mirror surfaces, including those in the main optical path, those in the IFC optical path and those in any chopper reference view path and any reflective optical surface on a chopper, shall meet or exceed the requirements of MIL-M-13508C paragraph 4.4.6 (with regard to adhesion of coatings) and MIL-M-13508C paragraph 4.4.5 (with regard to abrasion resistance and cleanability).

All interference film coatings on optical surfaces, including antireflection coatings on lenses and the warm and cold spectral filters, shall meet or exceed the general provisions of MIL-F-48616.

4.4.3.7 Obscurations

The design of the TSS shall be consistent with meeting all of the requirements of Section 3.3.7.

4.4.3.8 [Deleted]

4.4.3.9 [Deleted]

4.4.3.9.1 [Deleted]

4.4.3.9.2 [Deleted]

4.4.4 Radiometric Requirements

4.4.4.1 Chopper

A Chopper shall be placed in the optical path near the focal point of the primary mirror. The chopper and associated optics shall be arranged such that the detectors view alternately the atmospheric scene and an appropriate low-radiance reference.

4.4.4.1.1 Chopper Performance

The chopper shall be capable of operating over a frequency range of at least 490-510 Hz. The chopping waveform shall have a first harmonic amplitude no less than 90% of that for an ideal squarewave of the same amplitude as the actual waveform.

4.4.4.1.2 Chopper Temperature Stability

Under worst-case predicted thermal inputs during continuous instrument operation, the rate of change of chopper blade temperature shall not exceed 30 mK/min.

4.4.4.1.3 Chopper Reference Signal

A reference signal shall be provided by the TSS at the chopper frequency. This signal shall have a phase relationship to the chopped optical waveform that is constant to within 2.0 μs over any 1 min. period.

4.4.4.1.4 Chopper Phase Stability

Phase noise in the chopped optical signal with respect to the chopper reference signal, in a 40 Hz band centered on the chopper frequency, shall not exceed 5.0 mrad rms during steady-state operation.

4.4.4.2 Optical Transmission

Optical transmission of the TSS optical components shall be sufficient to allow the instrument-level optical transmission requirements in Section 3.3.8 to be met.

4.4.4.3 Transmissive Optical Elements

There shall be no transmissive optical elements in the optical path unique to either the atmospheric scene view or to the chopper reference view. Transmissive elements may be used in the optical path common to both views, i.e. between the Chopper and the Detectors.

4.4.5 Mechanical Requirements

4.4.5.1 Scanner Axis Requirements

4.4.5.1.1 Azimuth Axis

The Scanner azimuth axis of rotation shall be fixed with respect to the Optical Bench and shall:

a. be parallel to the TRCF Z-axis within 60 arcsec
b. pass within 1 mm of the point of intersection of the POA and the scan mirror surface when the scan mirror is in the Scan Datum position

4.4.5.1.2 Elevation Axis

The Scanner elevation (moveable) axis of rotation shall be:

a. orthogonal to within ±0.07° of the azimuth axis over the elevation axis motion range specified in Section 4.4.10.1.
b. parallel to within ±0.05° of the scan mirror surface
c. located within 8 mm of the point of intersection of the POA with the scan mirror surface, for all mirror positions within the operational scan range

4.4.5.2 Dynamics Requirements

4.4.5.2.1 TSS Stiffness

The TSS, configured for launch, shall have a fixed base frequency of greater than or equal to 70 Hz, with 100 Hz or above as a design goal.

The TSS shall also be sufficiently stiff to meet the specified on-orbit operational pointing stability requirements.

4.4.5.2.2 Isolation from Baseplate

Any mechanism, including the entire OBA, that requires restraint during vibration test and launch shall be caged without requiring power to maintain the caged or uncaged condition, and shall be capable of being caged or uncaged by command or by manual operation of accessible locking devices.

4.4.5.3 Mass

The mass of the TSS shall not exceed the value specified in Table 5.1-1.

4.4.5.4 Envelope

The envelope of the TSS shall be as specified in SP-HIR-214, STH to TSS ICD.

4.4.5.5 [Deleted]

4.4.5.6 TSS Mechanical Interfaces

4.4.5.6.1 Instrument Structure

The TSS interface with the STH shall be in accordance with SP-HIR-214, STH to TSS ICD.

4.4.5.6.2 Gyro Mechanical Unit

The TSS (optical bench) interface with the GMU shall be in accordance with SP-HIR-234, GSS to TSS ICD.

4.4.5.6.3 Detector Dewar

The TSS interface with the Detector Dewar shall be in accordance with SP-HIR-245, TSS to DSS ICD.

4.4.5.6.4 IFC Black Body

The TSS interface with the IFC Black Body shall be in accordance with SP-HIR-246, TSS to IFC ICD.

4.4.6 Electrical Requirements

4.4.6.1 Power Allocation

The TSS power consumption shall not exceed the value specified in Table 5.1-2.

4.4.6.2 TSS Electrical Interfaces

The TSS has electrical interfaces with the IPS and the PSS. All interface characteristics, including, but not limited to, signal definitions, connector identification, pin assignments, and connector locations, shall be as defined in SP-HIR-247, TSS to IPS ICD; and SP-HIR-249, TSS to PSS ICD.

4.4.7 Thermal Requirements

The TSS shall meet all performance requirements specified herein when exposed to the thermal environments specified in Sections 3.8 and 3.11.

4.4.7.1 Thermal Interfaces

The TSS thermal interfaces are:

a. radiative interface with the internal Instrument environment
b. radiative interface with the external environment
c. conductive interface with the STH
d. conductive interface with the DSS
e. conductive interface with the GMU
f. conductive interface with the IFC

All thermal interface characteristics including surface finishes shall be as defined in SP-HIR-111, Thermal Interface Requirements Document.

4.4.7.2 [Deleted]

4.4.7.3 Mirror Temperature Knowledge

The Scan and Primary Paraboloid mirrors shall be equipped with temperature sensors of type and quantity sufficient to provide knowledge, during normal instrument operation, of the reflecting-surface temperatures of each mirror as follows:

a. The average temperature of the illuminated area shall be known to an absolute accuracy of ±2 K.

b. The temperature difference between any two points within the illuminated area shall be known to a differential accuracy of ±0.25 K

c. The resolution of the sensor outputs shall be no coarser than 0.1 K.

4.4.7.4 Mirror Temperature Stability

For all mirrors in the radiometric optical paths, including the scan mirror, the surface temperature averaged over the illuminated area shall not change at a rate greater than 30 mK/min during periods of steady-state data acquisition.

4.4.7.5 Scan Mirror Temperature Gradients

The magnitude and distribution of temperature gradients on the scan mirror reflecting surface shall be constrained by design such that the following conditions are met:

a. At any fixed azimuth angle within the azimuth scan range (including the IFC blackbody view), the variation in the mean temperature of the scan mirror surface within the beam footprint shall change by no more than 0.01 K while moving the mirror through the full elevation range.

b. At any fixed elevation angle within the elevation scan range, the variation in the mean temperature of the scan mirror surface within the beam footprint shall change by no more than 0.1 K while moving the mirror through the full azimuth scan range (including the IFC blackbody view).

4.4.8 Environments

The TSS shall be designed such that the Instrument meets the overall performance requirements after exposure to the environments specified in Section 3.11.

4.4.9 Reliability Requirements

The TSS shall be designed to have a reliability factor as specified in Table 5.1-3.

4.4.10 TSS Pointing and Scanning Requirements

The TSS makes measurements of the scan mirror angles about the two scanner motion axes so as to furnish part of the data required to allow the position in the atmosphere corresponding to each given radiance sample to be determined in ground processing.

In order to describe the relevant requirements, the definitions made in Section 3.5 above, of relative elevation and azimuth angles, are again used.

The following requirements are specific to the TSS. There are related requirements for the Gyro subsystem, which must also be met in order to meet the Instrument specifications of Section 3.5.

4.4.10.1 Boresight Angle and Axis Motion Ranges

The boresight placement, relative to the TRCF, and the minimum required ranges of motion for the Scanner axes, are given in Table 4.4.10.1-1.

NOTE: The required axis motion ranges are given in shaft angles (not LOS angles) relative to the Scan Datum Position, and include all required scan geometry factors and margins.

Parameter	Elevation	Azimuth
Boresight-to-TRCF	25.3°± 60"	0°± 60"
Axis Motion Ranges	–2.27° to +1.62°	–24.5° to +29°

Table 4.4.10.1-1 Boresight Angle and Axis Motion Ranges

4.4.10.2 Elevation Requirements

4.4.10.2.1 Scan Rate

The TSS scan system shall be designed to support the requirements in Section 3.5.1.2. If a system employing motion sensors mounted to the Optical Bench is used for meeting these requirements, the outputs of the motion sensors shall be available to the IPS on demand at any rate up to the radiometric chopping rate, for diagnostic use.

4.4.10.2.2 Elevation Angle Knowledge Requirements

Note: See definitions in Section 3.5.

The following requirements on retrieved elevation angle knowledge, relative to the TRCF, shall be met in the on-orbit thermal and vibrational environments specified in Section 3.11:

a. Within any one Global Mode elevation scan (nominal duration 10 s) the random error in the knowledge of the elevation angle difference between any two radiometric samples, measured with respect to the TRCF and filtered according to the PLPF characteristics defined in Section 3.5c, shall not be more than 1.5 arcsec, 3 σ; this shall include the pointing knowledge error (if any) induced by the presence of random ILOS jitter as specified in Section 4.4.10.2.3. It may be assumed for the purposes of this requirement that the scan mirror has not been commanded to move in azimuth during the elevation scan.

b. Within any one Global Mode elevation scan (nominal duration 10 s) the systematic error in the determination of the elevation angle difference between any two radiometric samples, measured with respect to the TRCF, shall not exceed the greater of 0.14% of the relative angle or 0.2 arcsec. It may be assumed for the purposes of this requirement that the scan mirror has not been commanded to move in azimuth during the elevation scan.

c. For any specified pointing direction **A** within the elevation and azimuth ranges specified in Sections 3.5.1.1 and 3.5.2.1, if the scanner is periodically commanded to direction **A** at time intervals of Δt, with intervening periods of arbitrary scanner motion, then the **differences** between the LOS elevation angles of the repeated occurrences of **A** as determined from the scanner sensor outputs and the calibration data, and the corresponding true LOS elevation angles of the line-of-sight in TRCF coordinates (as defined in Figure 3.5-1), shall form a data set with a 3 σ value not exceeding 2.0 arcsec. This criterion shall be met for any value of Δt in the range of 10 s to 66 s, or in the range of p–132 s to p+132 s, where p is the orbital period, and with the scanner data filtered according to the PLPF characteristics defined in Section 3.5c.

d. For any two vertical scans (here designated Scan A and Scan B) separated in time by any interval in the range of 10 s to 66 s, or by any interval in the range of p–132 s to p+132 s, where p is the orbital period, it shall be possible to retrieve the elevation angle difference, relative to the TRCF, between any radiometric sample in Scan A and any radiometric sample in Scan B, with an error of at most 2.0 arcsec, 3 σ, by using the following information only:

   1. Encoder data
   2. Wobble Sensor data
   3. Conversion coefficients and calibration tables, if any, determined during ground calibration
   4. At most two coefficients, C_0 and C_1 to be determined from on-orbit measurements and to be applied as a linear correction to the LOS elevation angle according to the equation,

   $$\theta = C_0 + \theta' + C_1\,\phi',$$

   where θ' and ϕ' are the estimates of LOS elevation and azimuth angles based upon information items 1-3.

   For purposes of verification of this requirement at the instrument level (pre-launch), it may be assumed that the coefficients C_0 and C_1 will be updated to their theoretically optimum values once per ten minutes.

4.4.10.2.3 Elevation Angle Jitter Requirements

The TSS shall incorporate such design features as required to enable the instrument-level elevation angle jitter requirements of Section 3.5.1.5 to be met.

4.4.10.2.4 Fixed Angle Mode

The TSS shall be capable of holding a fixed LOS elevation angle with resolution and stability characteristics satisfying the requirements of Section 3.5.1.4.

4.4.10.3 Azimuth Requirements

4.4.10.3.1 Azimuth Scan Increment and Settling Time

The following requirement may be verified in the absence of vibration sources external to the scanner.

The Scanner shall be capable of stepping 7.5 ° in azimuth shaft angle in either direction to any new commanded azimuth shaft angle within the azimuth motion range specified in Section 4.4.10.1, and settling to within ±0.025 ° of the commanded azimuth shaft angle within 1.0 s as shown in

Figure 4.4.10.3.1-1. Azimuth shaft angles shall be commandable over the full azimuth motion range specified in Table 4.4.10-1 in increments of 10 arcsec or less.

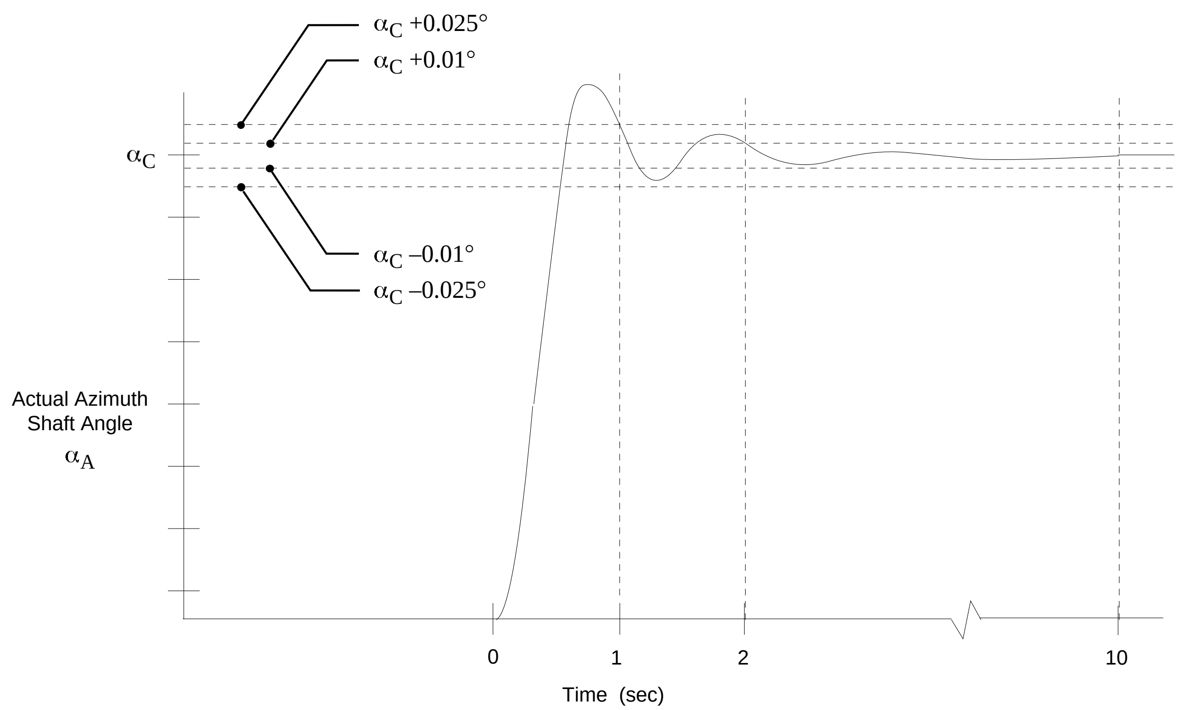


Figure 4.4.10.3.1-1 Azimuth Step and Settle Requirements

4.4.10.3.2 Azimuth Slew Rate

The following requirement may be verified in the absence of vibration sources external to the scanner.

The azimuth shaft angle slew rate shall be commandable over the range –30 °/s to +30 °/s in increments no coarser than 0.025 °/s. At any time after 1 s following initiation of a slew maneuver, the actual slew rate shall differ from the commanded rate by at most the greater of 10 % of the commanded rate or 0.05 °/s.

4.4.10.3.3 Azimuth Pointing Accuracy and Knowledge

The following requirements shall be met over the on-orbit thermal and dynamic environments specified in Sections 3.8 and 3.11:

a. For any commanded azimuth shaft angle within the azimuth motion range specified in Table 4.4.10-1, the actual shaft angle, α_A, shall equal the commanded shaft angle α_C within the following limit at all times between 2.0 and 10.0 seconds (See Figure 4.4.10.3.1-1) following the initiation of an azimuth step of up to 7.5 ° shaft angle:

$$|\alpha_A - \alpha_C| \leq 0.01°.$$

b. For any two Global Mode vertical scans (of approximately 10 s duration each) separated in time by any interval in the range of 10 s to 66 s, or by any interval in the range of *p*–132 s to *p*+132 s, where *p* is the orbital period, the difference between the mean ILOS azimuth angle over the first vertical scan and the mean ILOS azimuth angle over the second vertical scan, relative to the TRCF, shall be known with an unsigned error of at most 72 arcsec. These means shall be taken over the full duration of the vertical scans, excluding 1.0 s of settling time following the initiation of any azimuth step of up to 7.5 ° shaft angle. This requirement shall apply where the two vertical scans are taken at any two fixed azimuth shaft angle settings within the scanner motion range specified in Table 4.4.10-1.

c. At all times, the absolute ILOS azimuth angle relative to the TRCF shall be known to within 90 arcsec.

4.4.10.3.4 Azimuth Angle Jitter Requirements

The following requirement on jitter must be met in the on-orbit thermal and vibrational environments specified in Sections 3.8 and 3.11:

The integrated LOS azimuth jitter referred to inertial space shall not exceed 30.0 arcsec, 3 σ.

4.4.10.3.5 Azimuth Angle Knowledge Resolution and Sampling

The azimuth shaft angle transducer resolution shall be 5.0 arcsec or less, and the transducer output shall be available to the IPS on demand at any rate up to the radiometric chopping frequency. [Note: This requirement is derived from the need to correct the retrieved ILOS elevation angle for the effect of random azimuth motion at large ILOS azimuth angles.]

4.4.10.4 Calibration Aids

There shall be a first-surface flat mirror permanently attached to the Optical Bench Structure or to some part of the Optical Bench Assembly that is fixed with respect to the Optical Bench Structure. This mirror shall have the following characteristics:

Clear Aperture:	≥12 mm
Flatness:	λ/2 at 633 nm over central 90% of aperture
Reflectivity:	>0.9 at 633 nm

The location of this mirror and the direction of the mirror normal shall be chosen so as to provide a clear line-of-sight between the mirror and an external autocollimator, either through the main viewing (hotdog) aperture or through a special view-port. Details of the mirror viewing geometry shall be agreed with Oxford University to ensure compatibility with the HIRDLS Calibration Facility.

4.5 Detector Subsystem

4.5.1 Subsystem Description

The HIRDLS Detector Subsystem (DSS) consists of 21 HgCdTe IR detectors, and associated optical filters of the Cold Filter Assembly (CFA), contained in a hermetic vacuum dewar and cooled to 60-65 K by the Cooler Subsystem. Each detector element has an instantaneous field of view in the atmosphere that extends 1 km vertically and 10 km horizontally. The detector outputs are amplified, analog filtered, digitized, and digitally filtered in the Instrument Processor Subsystem.

Figure 4.5.1-1 shows the Baseline Radiometric Channel Layout as projected into the atmosphere.

4.5.2 [Deleted]

4.5.3 Imaging Requirements

4.5.3.1 Cold Shield

A cold field of view shall enclose the focal plane to reduce the optical background on the detector elements. The cold shield aperture shall enclose the minimum aperture possible at its location. The limiting aperture shall be formed by a knife edge of radius not greater than 0.090 mm. The inside surfaces shall have an effective emissivity greater than 0.95 in the spectral band from 6 to 18 µm. The front side of the cold shield aperture shall have a reflectance less than 0.1. The outside surface of the cold shield shall have an emissivity of less than 0.05.

4.5.3.2 Optical Filters

A multi-layer coated bandpass filter shall be mounted immediately in front of each detector element, and maintained by the CSS at a temperature within 2.0 K of the detector temperature.

The performance requirements for these cooled bandpass filters are given in SP-HIR-69.

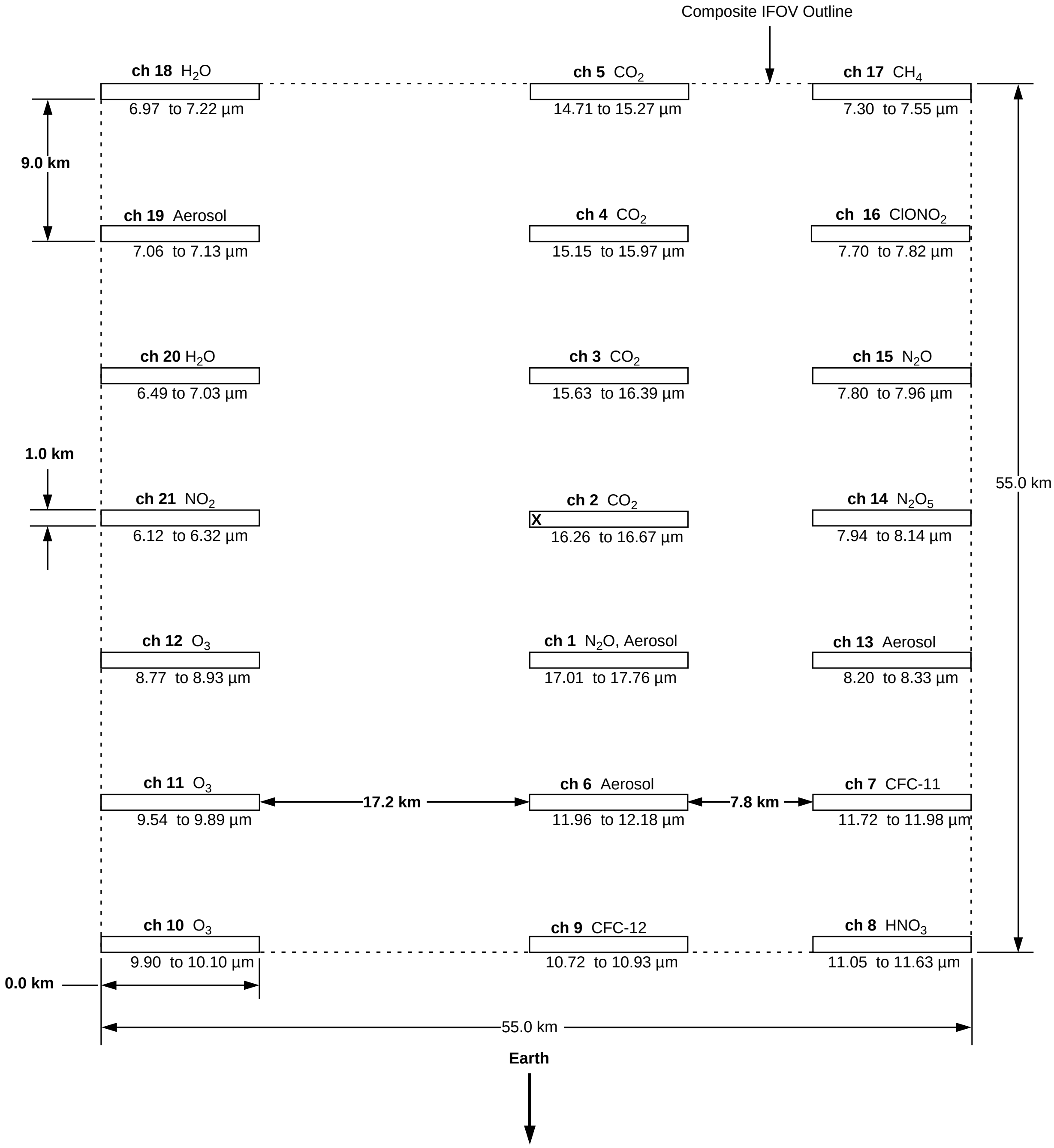
4.5.3.3 Window

The DSS shall include a plane window 2.0 mm thick of AR coated optical grade ZnSe.

4.5.4 Radiometric Requirements

4.5.4.1 Noise Equivalent Power Density (NEP´)

The NEP’ performance of the DSS shall be as required for meeting the instrument-level NEP’ requirements given in Section 3.4.5.2.



Notes

1 This view is the projection into the atmosphere of the field stop array as viewed from the Instrument.

2 Point **X** is the image in the atmosphere of the origin, at the centre of the field stop array, of the telescope Projected Optical Axis (POA).

3 Definitive parameters are in **bold** type. Parameters in light type are for information only.

DMW-990129

Figure 4.5.1-1 Baseline Radiometric Channel Layout

4.5.4.2 Responsivity

4.5.4.2.1 Responsivity Uniformity

Along the horizontal (long) dimension, the detector elements shall have, as a goal, the best attainable responsivity uniformity; however, it is not intended that the detector design should significantly sacrifice noise performance or mean responsivity in order to reduce non-uniformity caused by minority-carrier sweepout.

Along the vertical (short) dimension, define the optical width of each detector as the full width at half maximum (FWHM) of its response to a diffraction-limited line source parallel to the detector long dimension and scanned in the direction of the short dimension. Then, as a design goal, over the central 85% of the optical width, the response to this scanned line source should vary by no more than ±3.0% of the average response over the same width.

4.5.4.2.2 [Deleted]

4.5.4.3 [Deleted]

4.5.4.4 [Deleted]

4.5.5 Mechanical Requirements

4.5.5.1 Envelope

The DSS shall be contained in the envelope specified in SP-HIR-245, TSS to DSS ICD.

4.5.5.2 Mass

The mass of the DSS shall not exceed the value specified in Table 5.1-1.

4.5.5.3 Mechanical Interface

The DSS mechanical interface with the TSS shall be as defined in SP-HIR-245, TSS to DSS ICD.

4.5.5.4 [Deleted]

4.5.5.5 Mechanical Design

The focal plane and associated cooled optical components shall be located in an evacuated and hermetically sealed volume.

4.5.6 Electrical Requirements

4.5.6.1 Output

Electrical connections to the detectors and temperature sensors shall be made through the vacuum wall of the dewar via hermetic feedthroughs.

4.5.6.2 [Deleted]

4.5.6.3 [Deleted]

4.5.6.4 Electrical Interface

The DSS signal and power interfaces with the IPS shall be as specified in SP-HIR-257, DSS to IPS ICD.

The electrical conductors between the Detector Dewar and the Preamplifier modules shall be fully enclosed within a shield which is grounded to the chassis of both modules.

4.5.6.5 Power Allocation

The DSS power consumption shall not exceed the allocation specified in Table 5.1-2.

4.5.7 Thermal Requirements

4.5.7.1 Thermal Interface

The DSS thermal interfaces are:

a. conductive interface with the CSS
b. radiative interface with the internal Instrument environment
c. conductive interface with the TSS

All thermal interfaces shall be as defined in SP-HIR-111, Thermal Interface Requirements Document.

4.5.7.2 DSS Cryogenic Heat Load

The total cryogenic heat load on the CSS from all DSS sources shall not exceed 700 mW.

4.5.7.3 Thermal Cycling

All of the functional components of the DSS shall be designed to allow the requirements of Sections 3.3.3, 3.4.2 and 4.5.4 to be met over the operational lifetime of the Instrument, following up to 250 temperature cycles of the focal plane assembly consisting of cool down from 300 K to 60 K and warm up from 60 K to 300 K.

4.5.8 Environments

The DSS shall be designed such that the Instrument meets the overall performance after exposure to the environments specified in Sections 3.8 and 3.11.

4.5.9 Reliability Requirements

The DSS shall be designed to have a reliability factor as specified in Table 5.1-3.

4.6 In-Flight Calibrator Subsystem

4.6.1 Subsystem Description

The In-Flight Calibrator Subsystem (IFC) is an integral part of the HIRDLS in-flight calibration scheme. In order to achieve the required radiometric accuracy over time, it is necessary to re-calibrate the radiometric signal path at short intervals by viewing reference cold and warm sources. The cold calibration view is achieved by directing the LOS sufficiently high in the atmosphere that the detectors are all effectively viewing cold space. The IFC consists of a small-area blackbody and associated heater control and temperature monitoring electronics which, in conjunction with an off-axis paraboloid mirror in the TSS, provides an effective large-area blackbody within the Instrument enclosure to which the LOS may be directed for the warm calibration view.

4.6.2 Modes of Operation

IFC modes of operation shall be defined so as to support the Instrument modes of operation defined in Section 3.2.

4.6.3 [Deleted]

4.6.4 Radiometric Requirements

The effective emissivity of the IFC Blackbody shall be not less than 0.997.

4.6.5 Mechanical Requirements

4.6.5.1 Envelope

The IFC shall be contained in the envelope specified in SP-HIR-216, STH to IFC ICD; and in SP-HIR-246, TSS to IFC ICD.

4.6.5.2 Mass

The mass of the IFC Subsystem shall not exceed the value specified in Table 5.1-1.

4.6.5.3 Mechanical Interface

The IFC mechanical interface to the TSS shall comply with SP-HIR-246, TSS to IFC ICD.

4.6.5.4 [Deleted]

4.6.6 Electrical Requirements

4.6.6.1 IFC Subsystem Secondary Power Requirements

All IFC secondary power shall be provided by the IPS as defined in SP-HIR-267, IFC to IPS ICD.

4.6.6.2 Power Allocation

The IFC power consumption shall not exceed the value specified in Table 5.1-2.

4.6.7 Thermal Requirements

4.6.7.1 Temperature Range

The temperature of the IFC blackbody shall be controllable by the IPS to any setpoint in the following range: the minimum natural equilibrium temperature or 10 °C, whichever is higher; and 45 °C.

4.6.7.2 Temperature Sensing

a. The temperature of the IFC blackbody shall be monitored at a sample rate of not less than 1 sample/10 s.

b. The IFC blackbody radiative surface temperature shall be known to a resolution of 0.005 K or less, and with an absolute accuracy of 0.07 K over the operational life of the Instrument.

4.6.7.3 Temperature Control

The temperature of the IFC Blackbody shall be controlled to within ± 0.2 K of the setpoint.

4.6.7.4 Thermal Interfaces

All IFC thermal interfaces shall be as defined in SP-HIR-111, Thermal Interface Requirements Document,.

4.6.8 Environments

The IFC shall be designed such that the Instrument meets the overall performance requirements after exposure to the environments specified in Section 3.11.

4.6.9 Reliability Requirements

The IFC shall be designed to have a reliability factor as specified in Table 5.1-3.

4.7 Instrument Processor Subsystem

4.7.1 Subsystem Description

The Instrument Processor Subsystem (IPS) manages the Instrument side of the Instrument/Spacecraft command and telemetry (C&T) interface, and provides the centralized communications, data processing, timing, control, and housekeeping services required to coordinate the internal functions of the Instrument. The IPS contains one or more microprocessors, volatile and non-volatile memory, interface hardware, special purpose hardware (e.g. timers), and appropriate system and application software.

The IPS functional interfaces with other HIRDLS subsystems and with the Spacecraft are shown in Figure 4.7.1-1. All communication with the Spacecraft takes place over dual redundant MIL-STD-1553 buses, with the IPS acting as a remote terminal (RT). Within the Instrument, command and status information is passed between the IPS and other subsystems using serial communication over RS-422 circuits. Time-critical signals such as data strobes are generated by dedicated hardware in the IPS and are transmitted over dedicated unidirectional RS-422 circuits. As shown in the figure, the IPS also interfaces directly with certain sensors and actuators using analog and bi-level signals, to implement monitoring and control functions that are not provided within other subsystems.

NOTE: Throughout this document, “RS-422” shall be interpreted as an abbreviation for “ANSI/EIA/TIA-422-B-1994”.

4.7.1.1 Architectural Philosophy

The IPS serves as the logical single point of contact of the Instrument with the Spacecraft communications system, and thus, with the mission command and telemetry structure. The implementation of the IPS may include redundant and/or fault tolerant hardware and software, if necessary, to meet the subsystem reliability requirements.

Flexibility of HIRDLS operation in orbit is a prime requirement. To this end, subsystem interfaces to the IPS should be implemented as simply as possible. The task of control and monitoring of the instrument will be executed by the IPS, where it is most visible to ground control and can most easily be monitored and modified.

The "single point of contact" concept does not preclude the use of multiple embedded microprocessors to perform specific tasks in other subsystems; however, the number of functionally separate microprocessors in the Instrument should be kept to the minimum consistent with the required processing and I/O bandwidths, and conservative timing margins. All protocols used to enable such embedded microprocessors to communicate with the IPS should comply with the relevant definitions in the HIRDLS Command & Telemetry Handbook (C&TH). Code maintenance of embedded microprocessors from the ground will be performed using memory load and verification protocols operating through the IPS.

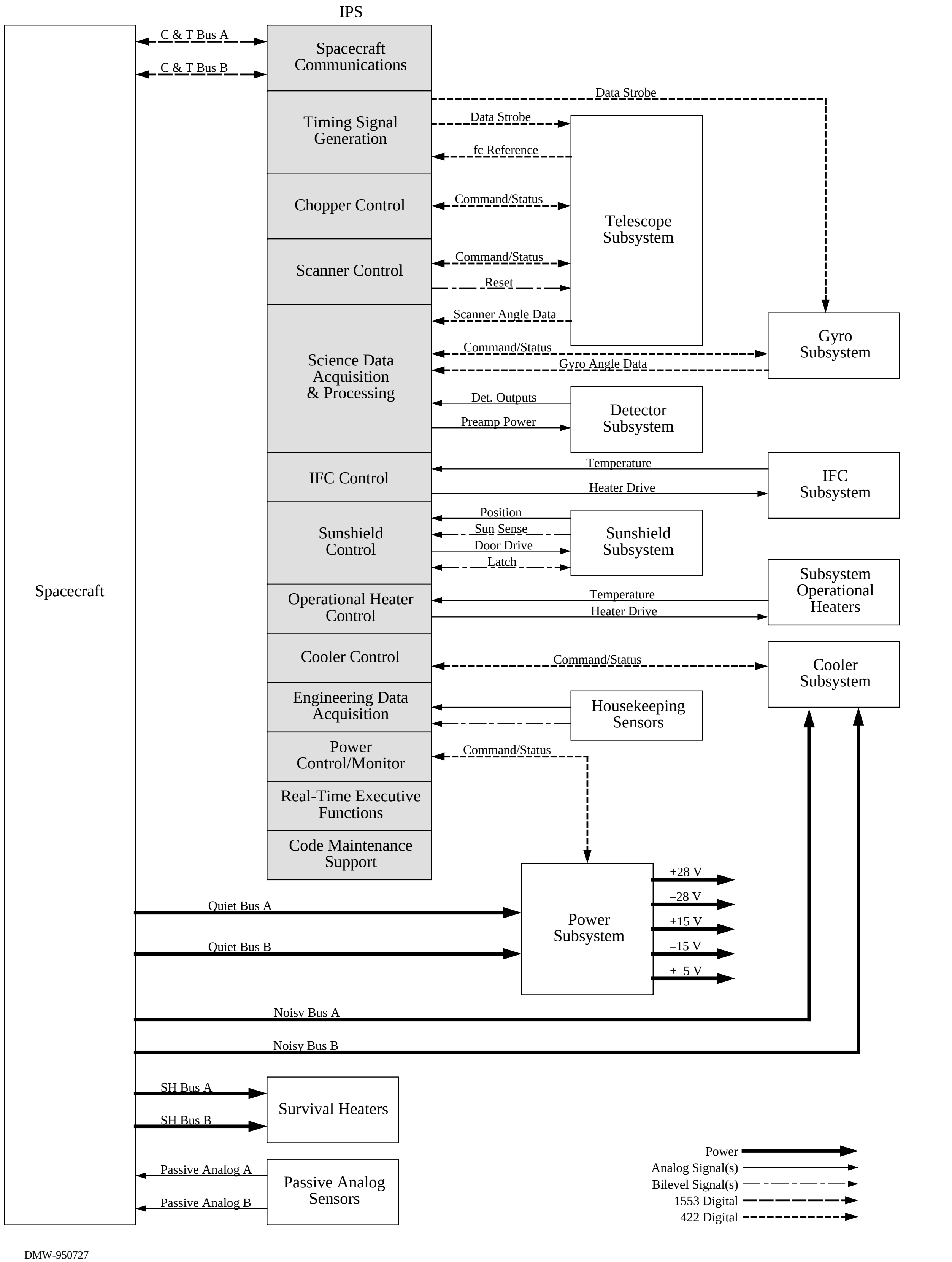


Figure 4.7.1-1 IPS Functional Interfaces Block Diagram

4.7.1.2 Subsystem Interfaces

4.7.1.2.1 [Deleted]

4.7.1.3 Operations Description

The IPS sub-blocks shown in Figure 4.7.1-1 are functions that must be performed by the IPS. These functions may be implemented in software or in a combination of software and dedicated hardware as appropriate.

4.7.2 Modes of Operation

IPS modes of operation shall be defined so as to support the Instrument modes of operation defined in Section 3.2.

4.7.3 Functional Requirements

4.7.3.1 Spacecraft and Subsystem Interfaces

4.7.3.1.1 Spacecraft Command and Telemetry (C&T) Interface

The Instrument-to-Spacecraft C&T interface shall comply with the interface protocol requirements specified in Section 3.9.3 and SP-HIR-103, C&TH. This interface shall also comply with the requirements of TRW-D26477, HSICD.

4.7.3.1.2 Gyro Subsystem Interface

The IPS-GSS interface shall conform to SP-HIR-237, GSS to IPS ICD; and to SP-HIR-103, C&TH.

4.7.3.1.3 Telescope Subsystem Interface

The TSS-IPS interface shall conform to SP-HIR-247, TSS to IPS ICD; and to SP-HIR-103, C&TH.

4.7.3.1.3.1 [Deleted]

4.7.3.1.3.2 [Deleted]

4.7.3.1.4 Detector Subsystem Interface

The DSS-IPS interface shall conform to SP-HIR-257, DSS to IPS ICD.

4.7.3.1.5 IFC Subsystem Interface

The IFC-IPS interface shall conform to SP-HIR-267, IFC to IPS ICD; and to SP-HIR-103, C&TH.

4.7.3.1.6 Sunshield Subsystem Interface

The SSH-IPS interface shall conform to SP-HIR-227, SSH to IPS ICD; and to SP-HIR-103, C&TH.

4.7.3.1.7 Cooler Subsystem Interface

The IPS-CSS interface shall conform to SP-HIR-278, IPS to CSS ICD; and to SP-HIR-103, C&TH.

4.7.3.1.8 Operational Heaters Interface

The IPS shall conform to the operational heater interface defined in the SP-HIR-247, TSS to IPS ICD.

4.7.3.1.9 Power Subsystem Interface

The IPS-PSS interface shall conform to SP-HIR-279, IPS to PSS ICD; and to SP-HIR-103, C&TH.

4.7.3.2 IPS Functions

This section defines the functions within the IPS that are required to support the communications, control, data processing, and health and safety monitoring functions of the Instrument under all modes of operation.

4.7.3.2.1 Spacecraft Communication

The IPS shall perform the following functions in order to support the Spacecraft/Instrument C&T interface.

4.7.3.2.1.1 Command Data

The IPS shall provide the ability to receive, store, and process information received over the Spacecraft C&T bus in the formats defined in Section 3.9. The IPS shall support reception of the command data stream at rates as defined in the HSICD, and according to the formats and contents specified in the C&TH.

4.7.3.2.1.2 Engineering Telemetry Data

The IPS shall provide the ability to output a subset of the Instrument engineering data as Engineering Telemetry Data over the Spacecraft C&T interface at the allocated average rate of 512 b/s. The IPS shall support packetizing the Engineering Telemetry Data as defined in Section 3.9.3.6.1. Engineering Telemetry Data shall be output in data packets of a fixed length regardless of the state of the Instrument as long as the IPS is active.

4.7.3.2.1.3 Science Telemetry Data

The IPS shall support outputting the Science Telemetry Data at rates up to the allocated normal rate of 50 kb/s and up to 100 kb/s for as long as 5 min./orbit for special purposes as required (see UIID Section 3.4.1). The IPS shall have the flexibility to use the available data bandwidth for variable proportions of Science Data, Engineering Data, memory dumps, and special diagnostic data.

With the exception of the Memory Dump mode defined in Section 4.7.3.2.1.3.2, the Science Telemetry Data format shall be, to the extent practicable, the same for all Mission sub-modes. If more than one Science Telemetry Data format is required, e.g. for special observing modes, the telemetry stream shall contain explicit header information in each data packet indicating which format is in use.

4.7.3.2.1.3.1 Science Telemetry Data Item List

The IPS shall provide the ability to output science telemetry according to the formats and content specified in the C&TH.

4.7.3.2.1.3.2 Memory Dump and Diagnostic Data

To aid in diagnosing problems and to verify newly uploaded parameters and/or code, the IPS software shall provide the ability to dump computer memory data via the Science Telemetry Data stream. Octets in the Instrument Data Field of the Science Data Packet, that are normally assigned to signal channel data, may be used for these dump data.

The IPS shall provide the ability to collect a specified set of parameters at higher than the normal Engineering Data rate and to transmit them in the Special Diagnostic Data telemetry. The IPS shall also provide the ability to modify the set of parameters to appear in the Special Diagnostic Data. Diagnostic data included in the Science data stream shall conform to the requirements of GIRD Section 6.5.10.

4.7.3.2.2 Timing Signal Generation

The IPS shall include the hardware and software required to generate a crystal-controlled master clock signal and from this signal to derive and distribute the timing signals that control the motion of the optical chopper and synchronize the acquisition and processing of radiometric and pointing data with the motion of the optical chopper.

4.7.3.2.2.1 Functional Description

The Telescope Subsystem will furnish to the IPS a Chopper Reference Signal at the optical chopping frequency f_C. This will be a square-wave signal having a fixed phase relationship to the optical chopping waveform. The IPS shall generate the following data strobe signals, synchronized to the chopper reference signal:

a. Detector sampling strobes

b. Scanner angle sampling strobe

c. Gyro data sampling strobe

d. Time Stamp strobe (if needed to meet the requirements of Section 4.7.3.2.3.4)

The generated signals shall also include a separately buffered copy of the Chopper Reference Signal for external use via a test connector.

It shall be possible to operate the Timing Signal Generation function from an external synchronization source via a test connector, in lieu of the Chopper Reference Signal, for test and diagnostic purposes.

4.7.3.2.2.2 Performance Requirements

4.7.3.2.2.2.1 Output Frequencies , Waveforms and Timing

Within a single radiometric sampling period ($6/f_c$ in the Global Mode) the relative times of occurrence of all of the sample strobes listed in Section 4.7.3.2.2.1 shall be known with a maximum uncertainty of 10 µs.

4.7.3.2.2.2.2 Phase Adjustment & Stability

Each timing signal derived from the chopper reference signal shall be independently adjustable in phase with respect to the chopper reference signal by use of a programmable digital delay that is adjustable over a range of at least $1.1/f_c$ in increments of 1 µs. All timing signals derived from the chopper reference signal shall have an rms jitter with respect to the active edge of the chopper reference signal not exceeding 100 ns.

4.7.3.2.2.2.3 Operation Without the Chopper

For testing and diagnostic purposes, the Timing Signal Generation function shall include the capability of generating all timing signal outputs from a crystal-derived reference within the IPS without the presence of the chopper in the system. This mode of operation shall be selectable by command.

4.7.3.2.3 Science Data Acquisition and Processing

Data in the Science Telemetry Data stream (including engineering data) shall be available to every IPS process. For this purpose all such data shall reside in RAM and shall be updated at a rate no less than the corresponding update rate in the Science Telemetry Data stream.

The Science Data Acquisition and Processing function of the IPS shall receive, process, and buffer data from the IR detector channels and shall receive and buffer the Scanner angle data from the TSS and the integrated rate data from the GSS. If OB motion sensing/compensation is implemented, the Science Data Acquisition and Processing function shall include the facility to receive and buffer motion sensor data from the TSS as required/selected for diagnostic purposes (see also Section 4.4.10.2.1). All of the above-defined data shall be formatted as required for inclusion in the Science Telemetry Data stream.

The IPS shall include sufficient digital processing and storage resources to support synchronous demodulation and digital filtering of all IR detector channels, and digital filtering of the Scanner and Gyro data streams. For estimation purposes, the processing and storage capability shall, as a minimum, be the equivalent of that required for:

a. 21 channels of 3-tap FIR filtering using 32-bit integer arithmetic and a sample rate of 1 kHz for each channel, and

b. 32 channels of 32-tap FIR filtering using 32-bit integer arithmetic and a sample rate of 84 Hz for each channel.

4.7.3.2.3.1 Detector Data

Each of the 21 detector signals from the DSS shall be amplified, analog filtered, sampled, and quantized. The characteristics of these processing functions, itemized below, shall apply over the lifetime of the Instrument in orbit.

a. Amplification: The gain of each channel shall be adjustable by passive component selection.

b. Analog Filtering: Each radiometric channel shall be filtered by an analog bandpass filter having the following characteristics:

    1. The amplitude response of the filter for any 60 Hz band within the range of 460 Hz to 540 Hz shall have a total variation of no more than 0.15 dB.

2. For any frequency in the range of 460 Hz to 540 Hz, the response relative to that at 500 Hz shall be stable over the lifetime of the Instrument in orbit (5 years) to within 0.02 dB of the measured initial value.
3. Within the frequency ranges of 0-100 Hz and >960 Hz, the response shall be no greater than –20 dB with respect to the response at 500 Hz.
4. For any 60 Hz band within the range of 460 Hz to 540 Hz, the total variation in group delay shall not exceed 40 µs.

c. Sampling: Each filtered detector signal shall be sampled at a rate of two samples per optical chopping cycle. Sampling shall be driven by the appropriate sample strobe signals generated within the IPS per Section 4.7.3.2.2.

The sampling function shall have the following characteristics:

Aperture delay from sample strobe	2 µs max.
Aperture jitter	500 ns max.
Sampling amplitude error	±0.5 quantization levels max.

d. Quantization: The sampled data shall be linearly quantized at the sampling rate, to a precision of 16 bits. The quantization process shall be monotonic and shall have no missing codes over the operating temperature range of the IPS. The quantization process shall have a maximum differential linearity error of 0.5 of the nominal quantization step size.

4.7.3.2.3.1.1 Channel Gain and Gain Stability

The radiometric channels within the IPS shall have appropriate gain and gain stability to ensure compliance with the instrument-level gain and gain stability requirements in Section 3.4.4.2 and Section 3.4.4.2.1.

4.7.3.2.3.1.2 [Deleted]

4.7.3.2.3.1.3 Channel Linearity

Over the dynamic range defined in Section 3.4.6, the gain of each channel between the detector output and the quantizer output shall be constant to within 0.5% of the value for a signal level at the maximum of the dynamic range. Over any 10% segment of the dynamic range, the gain at any signal level shall not differ from the average value over the segment by more than 0.2% of the average value.

4.7.3.2.3.2 Scanner Angle Data

The IPS shall provide the capability of receiving and buffering the scanner angle data stream transmitted by the TSS. Buffering of the scanner angle data shall include maintaining exact alignment between corresponding scanner angle data and IR detector data. Digital filtering of the scanner angle data stream, using separately defined filters for azimuth and elevation data channels, shall be a programmable option.

4.7.3.2.3.2.1 Scanner Angle Data Sampling Rate

Scanner angle data (both elevation and azimuth) shall be sampled at a rate not less than twice the optical chopping frequency to facilitate on-board digital filtering of the scanner angle data.

4.7.3.2.3.3 Gyro Data

The IPS shall provide the capability of receiving and buffering the gyro data stream transmitted by the GSS. Buffering of the gyro data shall include maintaining exact alignment between corresponding gyro data and IR detector data. Digital filtering of the gyro data stream, using separately defined filters for each axis channel, shall be a programmable option.

4.7.3.2.3.3.1 Gyro Data Sampling Rate

Gyro data shall be sampled at a rate not less than the radiometric sampling rate (see Section 3.4.7.3.2).

4.7.3.2.3.4 Time Stamp Data

All radiometric and pointing data associated with a single radiometric sampling period shall be transmitted in a single Science Telemetry Data packet that includes a Time Stamp derived from the HIRDLS master clock. This Time Stamp shall have a resolution of 50 µs or less. Spacecraft-furnished time information shall also be included in the Science Telemetry Data stream to the extent required to allow recovery through ground data processing of the relative time-of-occurrence of any two radiometric samples with the following maximum uncertainties: 500 µs for samples separated in time by any interval up to 1 orbit period; 1 part in 10^7 for samples separated in time by any interval greater than 1 orbit period within any period of uninterrupted operation of the Instrument.

4.7.3.2.4 Engineering Data Acquisition

The IPS shall provide Engineering Data acquisition for all subsystems including the IPS itself. Engineering Data are defined as the data necessary to assess health, configuration, and performance for a subsystem. Engineering Data acquisition shall be structured to be compatible with the telemetry data formats specified in Section 3.9.

4.7.3.2.4.1 Data availability

Engineering data shall be valid and available for acquisition whenever power is applied to the IPS and the IPS has completed a valid boot-up sequence.

4.7.3.2.4.2 Data Types

The following types of data have been identified as the minimum set required to assess Instrument health, configuration, and performance. Additional data types may be added as the subsystem design proceeds.

4.7.3.2.4.2.1 Thermal Engineering Data

The IPS shall be capable of processing thermal telemetry from all of the subsystems and providing that data to the Spacecraft telemetry stream.

Status data shall be provided for all heaters, include heater on/off and heater set-point (if applicable).

4.7.3.2.4.2.2 Power Engineering Data

Power monitoring shall be provided for all subsystems. These data shall include output voltages for all power supplies. Subsystem on/off status shall be included in the engineering data for all subsystems for which the power can be switched.

4.7.3.2.4.2.3 Instrument Operational Status

Sufficient state information shall be provided for all subsystems to allow confirmation of proper mode sequencing and subsystem configuration.

4.7.3.2.4.2.4 IPS Functional Status

IPS Engineering Data shall include, as a minimum, command/telemetry flags and monitors, table maintenance flags, and test status flags.

4.7.3.2.4.2.5 TSS Performance Data

Data shall be provided to allow performance analysis of the TSS.

4.7.3.2.4.3 Sample Rates

Each parameter making up the Engineering Data set as defined within the preceding sections shall be sampled at a frequency sufficient to support the telemetry rate for that parameter defined in the C&TH.

4.7.3.2.4.4 Data Range and Resolution

The representation of each engineering parameter in the Engineering Data set shall have a dynamic range of at least 2.0 times the expected maximum for that parameter, and shall saturate at the minimum or maximum representable values, respectively, for parameter values below or above the representable range.

At points of potential interaction (e.g. at the inputs to analog multiplexers) between analog signals being monitored as Engineering Data, the circuit design shall ensure that the predicted worst case out-of-range condition on any combination of channels does not degrade the measurement accuracy or precision of the remaining channels.

4.7.3.2.4.5 Data Processing

The IPS shall not be required to convert engineering data into engineering units. Processing shall be limited to the construction and transmission of engineering data set packets to the Spacecraft as defined in Section 3.9.3.6.

4.7.3.2.5 Chopper Control

The Chopper Control function shall implement the ability to turn the chopper on and off and to control any other parameters appropriate to the particular chopper implementation. The chopping frequency shall be programmable over a range of at least 490-510 Hz in increments of 0.1 Hz or less.

The Chopper Control function shall implement monitoring of Chopper operation by periodic sampling of all operating parameters provided by the Chopper Assembly.

4.7.3.2.6 Scanner Control

Commands issued by the Scanner Control function in the IPS to the Scanner shall include various power control, mode select, scan profile, timing, and status request commands as described below.

4.7.3.2.6.1 Scanner Command Protocol

Two Scanner command protocol formats shall be supported by the IPS, a block command format and a single command format.

The first command protocol format shall allow variable sized blocks of data to be passed from the IPS to the TSS. This block format shall consist of header information defining the number of data items in the block and the type of information contained in the block. At the end of the command block, a checksum for the header and data information contained in the block shall be included to allow verification of the block. Once the data block has been received and checksummed by the Scanner electronics, a validation status shall be passed from the Scanner back to the IPS via the Scanner Command/Status interface.

The second command protocol format shall allow single real-time commands to be passed from the IPS to the Scanner. Once the scanner electronics has received a single command, an acknowledgment of the receipt of the command shall be returned to the IPS via the Scanner Command/Status interface.

4.7.3.2.6.2 Scan Mode Select

The IPS Scanner Control function shall support selection of the Scanner mode. As a minimum, the following modes shall be supported:

a. Caged mode (if required; unpowered)

b. Power-up and Initialization mode

c. Stand-by mode / Safe mode

d. Datum Position mode

e. Scan mode

4.7.3.2.6.3 Scan Profile Commands

The IPS Scanner Control function shall provide all commands required to implement the scanning motions defined in Sections 4.4.10.2 and 4.4.10.3. As a minimum, commands shall be implemented to move the scan mirror to new specified elevation and/or azimuth angles at specified rates.

4.7.3.2.6.4 Scan Synchronization Command

Scan sequences shall begin in response to a synchronization command from the IPS Scanner Control via the Scanner Command/Status interface. Response time of the Scanner to the synchronization command shall not exceed 1.0 ms.

4.7.3.2.6.5 Reset Commands

Commands shall be provided from the IPS Scanner Control to implement a software reset and to activate the hardware reset line.

4.7.3.2.6.6 [Deleted]

4.7.3.2.6.7 Table Download

If the scanner controller within the TSS is implemented as a programmable device, the IPS shall support a scanner controller memory dump function on a non-interfering basis during normal operation to allow the IPS to perform continuous integrity monitoring of the scanner controller code and parameter tables.

4.7.3.2.6.8 [Deleted]

4.7.3.2.7 IFC Temperature Control

The IPS shall support IFC Black Body temperature control, in either hardware or software, in compliance with the IFC-IPS functional interface protocol defined in the C&TH, Section 2.6.

4.7.3.2.8 Sunshield Control

4.7.3.2.8.1 Sunshield Drive Mechanism Control

The Sunshield Control function shall include readout electronics for the Sunshield position sensor and the Sun Sensors, the drive electronics for the Sunshield drive motor, and the associated software. There shall be no single-point failure mode in the hardware supporting the Sunshield drive function that would prevent normal operation and control of the Sunshield. The drive control interface shall conform to SP-HIR-227, SSH to IPS ICD.

4.7.3.2.8.2 Sunshield Hold-down and Release Mechanism Control

The Sunshield Control function of the IPS shall include the interface electronics and associated software to operate, and monitor the position of, the HRM. This mechanism shall be bi-stable, i.e. it shall not require power to remain in the fully locked position or the fully unlocked position indefinitely. There shall be no single-point failure mode in the hardware supporting the HRM drive function that would prevent unlocking of the HRM. The HRM control interface shall conform to SP-HIR-227, SSH to IPS ICD.

4.7.3.2.9 Cooler Control

The IPS shall support the CSS control functions defined in the C&TH.

4.7.3.2.10 Operational Heater Control

The operational heater control section of the IPS shall contain the hardware required to interface with the operational temperature sensors and to drive the operational heater elements, and the software to implement the selected temperature control algorithm.

The IPS shall be capable of operating any heater in either of two modes, with PID coefficients or power dissipation individually settable for each heater:

a) Thermostatic Mode: in which the heater dissipation is controlled by software in order to maintain a demanded control sensor temperature, and where the control law has programmable PID coefficients

b) Constant Dissipation Mode: in which the heater dissipation is set via software to a constant value selectable by command in the range 0-90% of the rated heater power in 1%, or smaller, steps

4.7.3.2.11 Power Control/Monitor

The IPS shall provide a Power Control/Monitor function to handle the Command/Status interface with the PSS.

If the instrument power control strategy requires individual power converters or groups of secondary power outputs to be enabled/disabled, the required switching shall be implemented within the PSS and controlled by the IPS through the PSS Command/Status interface.

The Power Control/Monitor function shall provide for reception of all status flags and Engineering Data generated by the PSS.

4.7.3.2.12 Instrument Control and Coordination Functions

The IPS shall provide the overall control and coordination of all of the Instrument functions. As the primary interface to the Instrument, the IPS shall provide the capabilities necessary to operate the Instrument in accordance with the Instrument-level operational requirements.

4.7.3.2.12.1 Commanding Capabilities

Activities performed by the IPS in support of science observations and Instrument maintenance tasks shall be initiated and controlled through the use of command and data information received by the IPS from the Spacecraft interface. In order to support a flexible commanding interface, the IPS shall implement a commanding structure which will allow the Instrument to be commanded at either a high level, executing many related functions based on a single Spacecraft command block, or at a low level, executing a single function per command from the Spacecraft.

The IPS shall also support the ability to maintain Instrument operations for a minimum of 1 day without ground intervention.

4.7.3.2.12.2 Instrument Monitoring and Safety Requirements

The IPS shall be capable of collecting and monitoring key engineering data items for each of the critical Instrument components. Key Instrument parameters shall be monitored at a rate which is sufficient to allow the IPS to take protective action, if necessary, in response to an anomalous reading. The IPS shall be capable of performing pre-programmed corrective actions when an anomalous condition is detected. Each key safety parameter which must be monitored along with the monitoring criteria, monitoring rate, and the action to take when the violation is detected shall be documented.

4.7.3.2.12.3 User Processes

To allow the maximum flexibility in operation, the IPS software design shall implement a high-level science applications language conforming to SW-HIR-147B, SAIL Requirements Document.

4.7.3.2.12.4 Real-Time Executive Functions

The IPS shall provide the ability to complete each of its designated functions within the periods allocated. In addition to executing the routine tasks necessary to maintain the status of the Instrument, the IPS shall also provide the ability to respond to real-time, asynchronous events as required to meet the functional requirements of the subsystem.

Each active User Process shall be executed according to a priority table stored in volatile memory.

In the event that a User Process requires more time than is available, the Real Time Executive shall ensure that normal functioning is not impaired, terminating operation of the faulty User Process if required.

4.7.3.2.12.5 Reception of Spacecraft-Furnished Parameters

The IPS shall support reception of S/C-furnished time marks, time code data, and orbital parameters including equator crossing time marks, earth oblateness values, and other orbital data as appropriate. The IPS shall be capable of preserving or reconstructing the time of occurrence of time marks and orbital events to the full resolution furnished by the S/C.

4.7.3.2.13 Code Maintenance Support

The IPS shall provide the capability to upload and verify new data and/or code to any modifiable memory area within the IPS or within any subsystem with which the IPS communicates.

The IPS shall provide the capability to download the contents of any specified memory area within the IPS, or within any subsystem with which the IPS communicates, via the Science Data stream.

Loading of executable code to any subsystem other than the IPS shall only be required, if at all: a) as part of an Instrument Power-On mode transition sequence; b) as part of a ground-initiated code maintenance/revision activity. Loading of executable code to any subsystem, including the IPS, shall be initiated only by ground procedures and never by any automatic on-board process.

4.7.3.2.14 [Deleted]

4.7.3.2.15 [Deleted]

4.7.4 IPS Software Requirements

The IPS shall allow full operation in the absence of spacecraft timing information. The IPS shall be configured such that the Instrument is able to operate in a basic science data gathering mode after launch without the need for additional software to be uplinked.

In order to minimize the amount of code which needs to be uplinked should any modifications to instrument functionality be required, software should be written in a table driven manner wherever possible.

4.7.4.1 Boot State Requirements

When power is applied to the main electronics of the Instrument, the IPS processor will begin execution of the boot state software code. The primary purposes of the boot state are to provide the ability to load any portion of the modifiable memory area and to provide a method for transferring code and execution to the normal memory area. The primary requirements for the boot state software include: providing the functions necessary to upload and download data from/to the ground to/from the modifiable IPS memory area; providing the functions necessary to begin execution of the software at an uplinked address location; and providing the functions necessary to monitor and output information on the current state of the Instrument.

In support of the boot state, the flight software shall be able to recognize and process the commands necessary to initiate each of the valid boot state functions. A subset of the full Engineering Telemetry data shall be valid in the boot state and the Science Data memory dump format shall also be valid. All other data fields included in telemetry packets shall either contain valid data or shall be set to a value of zero.

4.7.4.2 Operate State Requirements

The IPS Operate State supports the main scientific functions of the Instrument. Within this state the IPS software shall be able to: configure each major subsystem; collect, format, and output normal Science Telemetry Data; collect and monitor engineering data; and format and output Engineering Telemetry Data. Multiple sequential calibrations and/or science data acquisition sequences may be performed while the Instrument is in the Operate State.

In support of the Operate State, the software shall be able to recognize and process the commands necessary to initiate each of the valid Operate State functions. The full set of Engineering Telemetry Data shall be valid in the Operate State and the normal, memory dump, and diagnostic Science Data formats shall also be valid.

4.7.5 Hardware Requirements

4.7.5.1 Functional and Performance Requirements

4.7.5.1.1 Processor

4.7.5.1.1.1 [Deleted]

4.7.5.1.1.2 [Deleted]

4.7.5.1.1.3 Processing Margin

The IPS processor shall provide processing margins sufficient to support the throughput margin requirements defined in Section 3.10.2.6.

4.7.5.1.2 Memory

The IPS shall contain both volatile and non-volatile memory. The memory will be utilized as defined herein.

4.7.5.1.2.1 Non-Volatile Memory

The non-volatile memory shall be divided into two sub-categories: Secure Memory and Reprogrammable memory. Secure Memory will consist of highly reliable, non-alterable memory that will contain the basic processor operating system. Reprogrammable memory will not be required to be as reliable and will allow changes to the memory contents.

4.7.5.1.2.1.1 Secure Memory

The Secure Memory shall be implemented using fusible link PROM devices.

Boot and maintenance flight code shall be located within the Secure Memory. Functionality contained within this memory shall provide the capability to reset the hardware and software, perform a limited subset of the self test tasks, communicate via the Spacecraft interface, and program the Reprogrammable Memory area.

The Secure Memory shall meet the following requirements:

a. Secure Memory capacity shall be implemented per the requirements defined within Section 3.10.2.6.

b. Secure Memory data word width shall be the same as that of the selected processor.

c. Secure Memory error detection shall be limited to software CRC testing. Results of this testing shall be included in the engineering data set.

4.7.5.1.2.1.2 Reprogrammable Memory

All executable flight code other than that contained within the Secure Memory shall be stored within the Reprogrammable Memory (RPM), which shall meet the following requirements:

a. The RPM shall be electrically modifiable.

b. RPM modification shall be under the control of code residing in Secure Memory. Modification shall be initiated by ground command only. Software interlocks shall be provided to reduce the probability of accidental modification.

c. RPM data word width shall be the same as that of the selected processor.

d. RPM access time shall be consistent with the processor resource utilization margins defined in Section 3.10.2.6. Throughput calculations shall be based on the functional requirements defined in Section 4.7.3.2.

e. RPM capacity shall be provided based on two complete copies of executable code and two complete copies of any lookup tables and other non-transient data, to which total shall be applied the resource utilization margins defined in Section 3.10.2.6.

f. Background CRC testing of the RPM shall be used to assess the integrity of the flight software. Results of this testing shall be included within the engineering data set. Automatic error correction shall be implemented if necessary to meet reliability requirements. If automatic error correction is included, corrective action reports shall be included within the engineering data set.

4.7.5.1.2.2 Volatile Memory

The IPS shall include random access memory (RAM) for storage of variable data. This shall include, but not be limited to, buffered command and telemetry packets, engineering data, science data, and intermediate results of calculations. The IPS shall have the capability of executing flight code located anywhere in the RAM address space. The IPS RAM shall meet the following requirements:

a. RAM capacity shall be provided based on the required storage capacity for all transient data plus one complete copy of executable code and one complete copy of lookup tables and other non-transient data, to which total shall be applied the resource utilization margins defined in Section 3.10.2.6..

b. RAM data word width shall be the same as that of the selected processor.

c. RAM access time shall support the processor resource utilization margins defined in Section 3.10.2.6. Throughput calculations shall include functional requirements defined in Section 4.7.3.2.

d. Automatic error correction shall be implemented if necessary to meet reliability requirements. Error correction status and activity shall be included within the engineering data set.

4.7.5.2 Mechanical Requirements

4.7.5.2.1 Mass

The mass of the IPS shall not exceed the value specified in Table 5.1-1.

4.7.5.2.2 Envelope

The IPU and the SPU shall be contained within the volumes defined in SP-HIR-217, STH to IPS ICD.

4.7.5.3 Electrical Requirements

4.7.5.3.1 Input Power Requirements

4.7.5.3.1.1 Power Allocation

The total power consumption of the IPS shall not exceed the allocation shown in Table 5.1-2.

4.7.5.3.1.2 Primary Power

The IPS will receive S/C Quiet Bus power via the PSS according to the power distribution configuration defined in SP-HIR-169. The primary power load characteristics of the IPS shall conform to the requirements in SP-HIR-279, IPS to PSS ICD.

4.7.5.3.1.3 Secondary Power

The IPS will receive regulated secondary power from the PSS according to the power distribution configuration defined in SP-HIR-169. The secondary power load characteristics of the IPS shall conform to the requirements of SP-HIR-279, IPS to PSS ICD.

4.7.5.3.2 Isolation and Grounding Requirements

4.7.5.3.2.1 Primary Power Grounding

Primary power returns shall be isolated from all other returns and from chassis ground by 10.0 MΩ dc or greater.

4.7.5.3.2.2 Secondary Power Grounding

Secondary power returns shall be isolated from the primary power returns by 10.0 MΩdc or greater.

4.7.5.3.3 Signal Electrical Interfaces

See Section 4.7.3.1.

4.7.5.3.3.1 [Deleted]

4.7.5.3.3.2 [Deleted]

4.7.5.3.3.3 [Deleted]

4.7.5.3.3.4 [Deleted]

4.7.5.3.3.5 [Deleted]

4.7.5.3.3.6 [Deleted]

4.7.5.3.3.7 [Deleted]

4.7.5.3.3.8 [Deleted]

4.7.5.3.3.9 [Deleted]

4.7.6 [Deleted]

4.7.6.1 [Deleted]

4.7.7 Thermal Requirements

4.7.7.1 [Deleted]

4.7.7.2 Thermal Interfaces

The IPS thermal interface to the STH shall comply with the SP-HIR-111, Thermal Interface Requirements Document.

4.7.8 Reliability Requirements

The IPS shall meet the general reliability allocation shown in Table 5.1-3.

The following Subsections, 4.7.8.1-4.7.8.5, present design guidelines for the choice of IPS architecture and components such that the HIRDLS science objectives can be met. It is not required that conformance to these guidelines be formally verified.

4.7.8.1 Functional Loss

The IPS should be designed for a probability of 0.975 of completing 2 years of ground testing and calibration, 3 years in storage, and 5 years of continuous operation in orbit without permanent loss of any functionality specified in this document, and without violating any of the constraints on error occurrence rates specified in the following paragraphs.

The IPS should be designed for a probability of 0.990 of completing 2 years of ground testing and calibration, 3 years in storage, and 5 years of continuous operation in orbit without permanent loss of any functionality for which the code resides in Secure Memory.

4.7.8.2 Data Loss

Data loss due to IPS malfunctions should not exceed 10 minutes in any 800 hour period. For purposes of this requirement, any period when data is output by the IPS during the persistence of any reported error condition or combination of error conditions that could possibly imply corruption of the data, should be considered a period of data loss.

4.7.8.3 Undetected Bit Errors

Undetected bit errors in the telemetry stream output to the Spacecraft C&T bus should not exceed 1 bit per 100 hours of operation at the allocated science data telemetry rate. For purposes of this requirement, a bit error is defined as any occurrence of a bit value in the telemetry stream that differs from the theoretically correct value, considering all digital inputs to the IPS and all A/D outputs within the IPS to be correct; and an undetected bit error is defined as a bit error that occurs independently of any IPS-generated error condition.

4.7.8.4 Uncommanded Resets

IPS resets, not initiated by ground command, should not exceed 1 reset in any 2000 hour period during which the IPS is powered.

4.7.8.5 Subsystem Command Errors

Commands generated by the IPS for controlling any other subsystem should differ in content or sequence from the theoretically correct values no more often than once per 10^7 commands issued to that subsystem.

4.7.9 Environments

The IPS shall be designed such that the Instrument meets the overall performance requirements after exposure to the environments specified in Section 3.11.

4.8 Cooler Subsystem

4.8.1 Subsystem Description

The Cooler Subsystem (CSS) consists of a Cooler Mechanical Assembly (CMA), and a Cooler Control Unit (CCU). The CSS provides active cooling for the DSS Detector Array, Cold Filter Assembly, and Cold Shield, which are located within the Dewar Unit. The DSS Dewar is mounted on the TSS Optical Bench.

The CMA consists of the balanced Compressor pair, Displacer with internal counter-balance, their mounting brackets, the Cooler Radiator Panel, the Cryovac Housing, and the Cold-Link/Flexible Vacuum Enclosure. The Compressor and Displacer on their respective mounting brackets are mounted in the plane of the Cooler Radiator Panel, which is in turn mounted to the STH. The Cryovac Housing is attached to the Displacer body. The Flexible Vacuum Enclosure provides a vacuum-tight interface between the Cryovac Housing and the DSS Dewar Unit while minimizing the transmission of mechanical vibration from the Cooler to the Optical Bench, and vice versa. The thermally conductive CSS Cold Rod and flexible S-Link join the Cold Tip of the Displacer to the DSS Dewar Cold Rod at the Cold Node. When the CSS is operating the Cryovac Housing will be evacuated.

The CCU consists of a set of Cooler drive, control, and power-conditioning electronics. The CCU is commanded by, and furnishes telemetry data to, the IPS. Normally the Cold Node temperature is accurately maintained, by CCU control of the compressor stroke amplitude, at a set point commanded by the IPS (nominally 62 K). Power for all CSS circuits is provided by the S/C, which switches power on Noisy Bus NBA or NBB, and is conditioned and converted within the CCU as required by the various CSS loads. Power is routed through the PSS, which provides NB on/off switching.

Heat from the Compressor and Displacer is conducted directly to the Cooler Radiator Panel and radiated to space. Heat from the CCU is radiated to space. During laboratory testing in air, Thermal GSE will be used to conduct heat from the Compressor and Displacer via a fluid-cooled interface.

4.8.2 States of Operation

CSS states of operation shall be defined so as to support the Instrument modes of operation defined in Section 3.2.

In the Instrument Mission Mode, the CSS shall be capable of operation in either of two cooling sub-states as follows:

a. Thermostatic: In this sub-state the CCU shall control the Compressor and Displacer stroke amplitudes in order to maintain an IPS-commanded temperature at the Cold Node.

b. Manual: In this sub-state the CCU shall maintain the Compressor and Displacer stroke amplitudes at an IPS-commanded value; no closed-loop temperature feedback shall be used.

In the Instrument Decontamination Sub-mode, the CSS shall be capable of operation in the Warm-up sub-state as specified in Section 4.8.4.3.2.1.

4.8.3 Mechanical Requirements

4.8.3.1 Envelope

The CSS CMA and CCU shall be contained within the maximum envelopes specified in the STH-CSS ICD, SP-HIR-218.

4.8.3.2 Mass

The mass of the CSS shall not exceed the value specified in Table 5.1-1.

4.8.3.3 Mechanical Configuration

4.8.3.3.1 General Configuration

All mechanical interfaces between the CSS and other subsystems shall be as defined in the STH-CSS ICD, SP-HIR-218, and the DSS-CSS ICD, SP-HIR-258.

4.8.3.3.2 [Deleted]

4.8.3.3.3 Cryovac Housing

The Cryovac Housing shall be attached to the Displacer so that a vacuum-tight seal exists at the mounting face.

4.8.3.3.3.1 Flexible Vacuum Enclosure Interface Port

The Flexible Vacuum Enclosure shall include an open, flanged port to allow the Cold Link to be connected to the DSS Cold Rod at the Cold Node. Once the Cold Node connection has been made, the Flexible Vacuum Enclosure shall be attached to the DSS Dewar so that a vacuum-tight seal exists at the mounting face.

4.8.3.3.3.2 Pumping Port

The Cryovac Housing shall include a Pumping Port with a minimum internal diameter of 12 mm, for the attachment of a GSE pumping stem, which will pass through the Displacer Mounting Bracket.

4.8.3.3.4 Cold Link and Flexible Vacuum Enclosure

The Flexible Vacuum Enclosure shall be attached to the Cryovac Housing so that it forms a vacuum-tight seal.

The dimensions and layout of the Cold Link and Flexible Vacuum Enclosure interfaces with the DSS shall conform to the DSS-CSS ICD, SP-HIR-258.

4.8.3.3.5 Cooler Control Unit (CCU)

The CCU mechanical/thermal interfaces with the STH shall conform to the STH-CSS ICD, SP-HIR-218.

4.8.3.4 Mechanical Performance

4.8.3.4.1 Peak Imbalance Force

During steady state operation with the Cold Node temperature at, or below 80 K, and with any combination of cryogenic heat load and operating frequency consistent with the requirements of Section 4.8.6.3, the peak exported imbalance forces, as measured on a dynamometer, shall not exceed 700 mN for the displacer, and 300 mN for the compressor. These limits shall apply independently to the first 7 harmonics of the operating frequency, including the fundamental f_0, and to any frequency in the range 500±20 Hz. During cool-down, the peak imbalance forces shall not exceed 1.0 N in any direction over the same measurement bandwidth.

4.8.3.4.2 Operating Frequency

The Cooler shall operate at a frequency within the range 30.5 Hz to 40 Hz (see also Section 4.8.6.3.).

4.8.3.4.3 Orientation in 1-g field

The Cooler Subsystem shall be capable of operation in a 1-g ground test environment, with the Compressor and Displacer in any orientation without damage or degradation.

4.8.3.4.4 Caging of Cooler Mechanisms

Caging of the Compressor and Displacer moving parts during launch is permitted, provided that it can be maintained without the use of electrical power, and the method of un-caging does not introduce a critical failure mode.

4.8.3.4.5 Cryovac Housing

4.8.3.4.5.1 Maximum Rate of Pressure Rise

When fully assembled, and with the Pumping Port and the DSS end of the Flexible Vacuum Enclosure blanked off, the Cryovac Housing shall be vacuum tight, with a maximum rate of rise in pressure, after evacuation to 1E–6 torr, of less than 1E–5 torr/day, including the effects of inward leaks and internal outgassing.

4.8.3.4.6 [Deleted]

4.8.4 Electrical Requirements

4.8.4.1 Input Power Requirements

4.8.4.1.1 Power Allocation

The CSS total power consumption shall not exceed the allocation specified in Table 5.1-2.

4.8.4.1.2 Primary Power

The CSS shall derive power from the S/C Noisy Buses NBA or NBB. Switching for NBA/NBB selection and NB power on/off will be provided externally to the CSS.

The CSS shall operate within specifications from Noisy bus power having the characteristics specified in the relevant subsections of GIRD Section 5.2. The load characteristics of the CSS shall conform to the requirements of GIRD Section 5.1.2.3 and Section 5.2.5.2.4.

4.8.4.1.3 Secondary Power

The CSS shall provide its own secondary power.

4.8.4.2 Grounding Requirements

4.8.4.2.1 Primary Power Grounding

Isolation between the Noisy Bus power or return line and the CCU chassis shall be greater than 2 M Ω. Isolation between primary and secondary grounds shall be greater than 2 M Ω, with a capacitance between grounds of less than 1 μF.

4.8.4.2.2 Secondary Power Grounding

CSS secondary power grounding shall conform to the configuration defined in SP-HIR-169, Section 7.5.

4.8.4.3 Command and Telemetry Requirements

4.8.4.3.1 [Deleted]

4.8.4.3.2 Control Commands

The CSS Control/Data interface shall conform to SP-HIR-103, C&TH; and to SP-HIR-278, IPS to CSS ICD.

4.8.4.3.2.1 IPS Control of Cold Node Temperature

The CCU shall be commandable to any of the sub-states described in Section 4.8.2.

In the Thermostatic sub-state, the range and resolution of the IPS-commandable temperature set point shall conform to the requirements of Section 4.8.6.1.

In the Manual sub-state, the Compressor and Displacer stroke amplitudes shall be capable of being set on command from the IPS over the range from 20 to 95% of maximum stroke amplitude with 0.1% resolution, while maintaining control of residual imbalance, except for an allowable temporary increase in imbalance to a level not exceeding ten times the limits specified in Section 4.8.3.4.1 for a time period not exceeding 30 s immediately following a change of amplitude setting.

In the Warmup sub-state, the CCU shall allow the Compressor and Displacer stroke amplitudes, and phase angle to be commanded to values that produce active warming of the Cold Node without the use of heaters.

4.8.4.3.2.2 Frequency Control

The CSS operating frequency shall be settable on command from the IPS with a resolution of 0.1 Hz or less over at least the range specified in Section 4.8.3.4.2.

4.8.4.3.2.3 [Deleted]

4.8.4.4 Engineering Data

The CCU shall provide performance-monitoring data to the IPS during all modes of operation. Engineering data for the CSS shall comply with the requirements of Section 4.7.3.2.4.

4.8.4.5 Electrical Interfaces

The CSS interface with IPS shall be as specified in SP-HIR-278. The CSS interface with the Power Subsystem shall be as specified in SP-HIR-289.

4.8.5 Software Requirements

CSS software shall meet the requirements of Section 3.10.

4.8.6 Thermal Requirements

4.8.6.1 Temperature Set-point Range

In Thermostatic sub-state the Cold Node temperature shall be commandable to any value in the range 57 K to 80 K with a resolution of 0.25 K or less.

4.8.6.2 Temperature Control Stability

In Thermostatic sub-state the temperature at the Cold Node, assuming a constant heat load, shall not vary by more than 0.25 K p-p in the CSS on-orbit environment as defined in Section 4.8.7.2.

4.8.6.3 Usable Cooling Power vs. Operating Frequency

Within the range of on-orbit environments specified in Section 4.8.7.2, the CSS shall be capable of maintaining a maximum temperature at the Cold Node of 62 K with an applied heat load of 700 mW, over the operating frequency range specified in Section 4.8.3.4.2.

4.8.6.4 Thermal Interfaces

The CSS shall meet the requirements of the Thermal Interface Requirements Document, SP-HIR-111.

4.8.6.4.1 Cooler Radiator Panel Interfaces

The Cooler Radiator Panel shall interface with the STH per SP-HIR-218.

4.8.6.4.2 [Deleted]

4.8.6.4.3 Interface to Instrument Thermal GSE

To facilitate laboratory operation of the CSS in air, the Cooler Mechanical Assembly shall provide attachment points for ITGSE as defined in SP-HIR-218A, STH to CSS ICD, Figures 6 and 7.

4.8.7 Environments

4.8.7.1 Ground and Launch Environments

The CSS shall meet all the requirements specified herein after exposure to the ground, storage, and launch environments specified in Section 3.11.

4.8.7.2 CSS On-orbit Environment

a. The CSS shall perform within specifications when the primary power voltage varies between 24 V and 35 V within a period of one orbit, at a maximum rate of change of 0.25 V/s.

b. [Deleted]

c. [Deleted]

4.8.8 Reliability Requirements

4.8.8.1 Lifetime

The CSS shall be designed to operate over the periods described in Sections 3.13.2 and 3.13.3 with a reliability factor as specified in Table 5.1-3.

4.8.8.2 Thermal Cycles of Operation

The Cooler Subsystem shall be capable of at least 500 cycles of operation over its Lifetime. A cycle of operation is defined as including cool-down of the Cold Node from ambient temperature to 80 K, operation at or below 80 K for an indefinite period at cryogenic heat loads consistent with Section 4.8.6.3, and warm up to ambient temperature.

4.8.8.3 Maintainability

The CSS shall be designed to be maintenance-free during its storage and operational life. The Cooler shall be a permanently sealed assembly requiring no servicing of the working fluid.

4.8.8.4 Pressurized System Design

The Cooler Subsystem shall meet the requirements of GIRD Section 3.6.5.

4.9 Power Subsystem

4.9.1 Subsystem Description

The Power Subsystem (PSS) consists of the Power Converter Unit (PCU). The PCU will receive Quiet and Noisy power from the redundant spacecraft buses, and provide to the other subsystems various combinations of unregulated and regulated power according to the power distribution scheme defined in SP-HIR-169.

4.9.2 Modes of Operation

PSS modes of operation shall be defined so as to support the Instrument modes of operation defined in Section 3.2.

4.9.3 Mechanical Requirements

4.9.3.1 Envelope

The PCU shall be contained within the envelope specified in SP-HIR-219, STH to PSS ICD.

4.9.3.2 Mass

The mass of the PCU shall not exceed the value allocated in Table 5.1-1.

4.9.3.3 Mechanical Interfaces

The mechanical interfaces of the PCU shall conform to SP-HIR-219, STH to PSS ICD.

4.9.4 Electrical Requirements

4.9.4.1 Input Power Requirements

4.9.4.1.1 Power Allocation Requirements

The total power dissipation of the PSS shall not exceed the value allocated in Table 5.1-2.

4.9.4.1.2 Primary Power Characteristics

The PCU will be provided power from the redundant Quiet power buses, QBA and QBB, and Noisy power buses, NBA and NBB. The PCU shall meet all performance requirements specified herein when furnished with primary power having the characteristics defined in GIRD Sections 5.2.5.1 through 5.2.5.1.5 as modified by the HSICD.

4.9.4.1.3 Bus Discharging

The PCU, notwithstanding the state of any internal primary power switching relays, shall at all times present to each spacecraft power bus a differential resistive load of 60 kΩ or less.

4.9.4.2 Output Voltage Requirements

The configuration of PCU outputs for the various subsystems shall conform to SP-HIR-169. Voltage regulation for regulated voltage outputs to the various subsystems shall conform to the requirements in their respective Internal Interface Control Documents, SP-HIR-2X9.

4.9.4.2.1-4.9.4.2.4 [Deleted]

4.9.4.3 Isolation and Grounding Requirements

4.9.4.3.1 Primary Power Isolation

Within the PCU, the isolation between different primary power buses (considering each bus as a power/return line pair) and between each primary power bus and the PCU chassis, shall be at least 10.0 MΩ and less than 1 μF. Isolation between the primary power buses and the secondary ground point shall be at least 10.0 MΩ and less than 1 μF.

4.9.4.3.2 Secondary Power Isolation and Grounding

The PCU shall provide a Secondary Ground Star Point (SSP) as the common ground reference for all loads receiving secondary power from the PCU. The SSP must be connected to the PCU chassis at one point only. When the link between the SSP and the PCU chassis is disconnected, the isolation between the SSP and the structure, and between the SSP and any primary power bus, shall be greater than 10.0 MΩ and less than 1 μF.

4.9.4.4 Control and Data Requirements

The PCU shall have control and data interfaces with the IPU as specified in SP-HIR-279, IPS to PSS ICD. The PSS control and data addresses and bit definitions shall conform to SP-HIR-103, C&TH.

4.9.5 Thermal Requirements

4.9.5.1 Thermal Interfaces

The PCU thermal interfaces shall conform to SP-HIR-111, Thermal Interface Requirements Document.

4.9.6 Environments

The PSS shall meet all the requirements as specified herein after exposure to the ground, storage, and launch environments specified in Section 3.11.

4.9.7 Reliability Requirements

The PSS shall be designed to have a reliability factor as specified in Table 5.1-3.

5 REQUIREMENTS SUMMARY

5.1 Subsystem Allocations

Subsystem	Basic Mass kg	Mass on Isolators kg	ITS Section Reference
Structure /Thermal Subsystem (STH)	39.0	0.0	4.1.3.2
Sunshield Subsystem (SSH)	5.0	0.0	4.2.4.2
Gyro Subsystem (GSS)	10.3	4.4	4.3.4.2
Telescope Subsystem (TSS)	46.4	30.0	4.4.5.3
Detector Subsystem (DSS)	0.8	0.8	4.5.5.2
IFC Subsystem (IFC)	3.7	0.9	4.6.5.2
Instrument Processor Subsystem (IPS)	22.0	0.0	4.7.5.2.1
Cooler Subsystem (CSS)	27.3	0.8	4.8.3.2
Power Subsystem (PSS)	9.5	0.0	4.9.3.2
Integration Hardware	22.0	3.9	
TOTAL	186.0	40.8	3.6.2.1

Table 5.1-1 Subsystem Mass Allocations

Subsystem	2-Orbit Average Power W	Peak Power W	ITS Section Reference
Structure /Thermal Subsystem (STH)	0.0	0.0	N/A
Sunshield Subsystem (SSH)	1.0	1.0	4.2.5.1.2
Gyro Subsystem (GSS)	22.0	50.0	4.3.5.1
Telescope Subsystem (TSS)	39.0	54.0	4.4.6.1
Detector Subsystem (DSS)*			4.5.6.5
IFC Subsystem (IFC)	4.0	4.8	4.6.6.2
Instrument Processor Subsystem (IPS)	45.0	57.0	4.7.5.3.1.1
Cooler Subsystem (CSS)	85.0	149.0	4.8.4.1.1
Power Subsystem (PSS)	42.0	48.0	4.9.4.2.5
TOTAL	238.0	N/A **	

*The DSS power allocation is included in the IPS power allocation.

** Peak power is not used simultaneously by all subsystems.

Table 5.1-2 Subsystem Power Allocations (Mission Mode)

Subsystem	Reliability Factor	ITS Section Reference
Structure /Thermal Subsystem (STH)	0.995	4.1.7
Sunshield Subsystem (SSH)	0.980	4.2.8
Gyro Subsystem (GSS)	0.985	4.3.9
Telescope Subsystem (TSS)	0.975	4.4.9
Detector Subsystem (DSS)	0.975	4.5.9
IFC Subsystem (IFC)	0.990	4.6.9
Instrument Processor Subsystem (IPS)	0.980	4.7.8
Cooler Subsystem (CSS)	0.910	4.8.8
Power Subsystem (PSS)	0.990	4.9.7
Instrument	0.798	3.13.1

Table 5.1-3 Subsystem Reliability Budget

6 PREPARATION FOR DELIVERY

6.1 General

Handling, storage preservation, marking, labeling, packaging, packing, and shipping of all deliverables shall be controlled by HIRDLS approved procedures. The procedures shall be developed in accordance with MAR Section 8.

6.2 [Deleted]

7 APPENDICES

7.1 Acronym List

ATC	Advanced Technology Center [LMMS, Palo Alto]
AR	Anti-Reflective
BEU	Blackbody Electronics Unit
BOL	Beginning Of Life
C&DH	Command & Data Handling
C&T	Command & Telemetry
C&TH	Command & Telemetry Handbook
CCD	Charge Coupled Device
CCP	Contamination Control Plan
CCU	Cooler Control Unit
CDR	Critical Design Review
CFA	Cold Filter Assembly
CHEM	Chemistry Mission
CIFOV	Composite Instantaneous Field of View
CLAS	Center for Limb Atmospheric Sounding
CMA	Cooler Mechanical Assembly
CPS	Cooler Power Supply
CPU	Central Processing Unit
CRC	Cyclical Redundancy Code
CSC	Computer Software Component
CSCI	Computer Software Configuration Item
CSS	Cooler Subsystem
DSS	Detector Subsystem
EEA	Encoder Electronics Assembly
EMC	ElectroMagnetic Compatibility
EMI	ElectroMagnetic Interference
EOL	End Of Life
EOS	Earth Observing System
FOV	Field Of View
FWHM	Full Width at Half Maximum
GEU	Gyro Electronics Unit
GIRD	General Interface Requirements Document
GMU	Gyro Mechanical Unit

GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
GSS	Gyro Subsystem
HIRDLS	High Resolution Dynamics Limb Sounder
HRM	Hold-down and Release Mechanism
HSICD	Hirdls-Spacecraft Interface Control Document
I/O	Input/Output
IAC	Interface Alignment Cube
ICD	Interface Control Document
IFC	In Flight Calibrator
IFOV	Instantaneous field of view
IGSE	Instrument Ground Support Equipment
IICD	Internal Interface Control Document
ILOS	Instantaneous Line Of Sight
IPS	Instrument Processor Subsystem
IR	InfraRed
IRCF	Instrument Reference Coordinate Frame
IRD	Instrument Requirements Document
ISO	International Organization for Standardization
ITGSE	Instrument Thermal Ground Support Equipment
ITS	Instrument Technical Specification
LMMS	Lockheed Martin Missiles and Space
LOS	Line Of Sight
LSB	Least Significant Bit
MAR	Mission Assurance Requirements
MLI	Multilayer Insulation
NASA	National Aeronautics and Space Administration
NB	Noisy Bus
NBA	Noisy Bus A
NBB	Noisy Bus B
NEN	Noise Equivalent Radiance
NVR	Non-Volatile Residue
OB	Optical Bench
OBA	Optical Bench Assembly
OBC	On-Board Computer (spacecraft)
OSS	Optical Subsystem

PAR	Performance Assurance Requirements
PCU	Power Converter Unit
PDR	Preliminary Design Review
PID	Proportional, Integral, Derivative
PLPF	Pointing Low-Pass Filter
POA	Projected Optical Axis
POSIX	Portable Operating System I/F for Computer Environments
PPL	(GSFC) Preferred Parts List
PSS	Power Subsystem
QBA	Quiet Bus A
QBB	Quiet Bus B
RAL	Rutherford Appleton Laboratory
RCF	Reference Coordinate Frame
RRP	Relative Response Point
RSS	Root-Sum-Square
RT	Remote Terminal
SAS	System Aperture Stop
S/C	Spacecraft
SDM	Sunshield Drive Mechanism
SEU	Scanner Electronics Unit
SHA	Survival Heater Bus A
SHB	Survival Heater Bus B
SMDP	Scan Mirror Datum Point
SMU	Scanner Mechanical Unit
SI	Système International d'Unités
SPU	Signal Processing Unit
SRCF	Spacecraft Reference Coordinate Frame
SRD	Science Requirements Document
SSD	Subsystem Specification Document
SSH	Sunshield Subsystem
SSP	Secondary (Ground) Star Point
STH	Structure/Thermal Subsystem
SVA	Space View Aperture
SW (S/W)	Software
TBD	To be determined
TBV	To be verified

TML	Total Mass Loss
TRCF	Telescope Reference Coordinate Frame
TSS	Telescope Subsystem
UCB	University of Colorado at Boulder
UIID	Unique Instrument Interface Document
UK	United Kingdom
VCM	Volatile Condensable Material
WFA	Warm Filter Array
WSE	Wobble Sensor Electronics

–END–